DESIGN AND PERFORMANCE OF GEOS-B LASER DETECTOR

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DESIGN AND PERFORMANCE

OF

GEOS-B LASER DETECTOR

ABSTRACT

The following report describes the design and performance of the laser detector employed in the Atmospheric Laser Scintillation Experiment aboard the GEOS-B satellite. The laser detector was designed and fabricated for Goddard Space Flight Center by Washington Technological Associates, Inc. of 979 Rollins Avenue, Rockville, Maryland 20852. Many of the graphs, and drawings used in this report are derived from work done by WTA.

Four laser detectors were fabricated and are referred to as units number 1, 2, 3, and 4 in this report. Unit number 2 was installed on the GEOS-B satellite.

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The frequency of modulation is expected to be predominately low (below 10 Hz) but some modulation may occur up to 500 Hz. A simple optical sensor will detect the strength of laser radiation impinging upon the satellite, and retransmit this information to a ground station via the satellite telemetry link. Telemetry link characteristics on GEOS-B would permit the system to respond to modulation frequencies as high as 80 Hz. While useful higher frequency information will be lost, we believe (based upon ground link experiments) that much of the useful observation of atmospheric scintillation can be performed below 80 Hz. This experiment (the first analysis of atmospheric scintillation on this type of link) will provide qualitative and quantitative data on the susceptibility of earth-spacecraft links to fading caused by atmospheric turbulence. It should thus serve as an important step in NASA's development of optical communication and tracking technology, by providing essential information on atmospheric turbulence necessary for future optical missions.

The ground laser station for this experiment will consist of the argon laser and tracking mount presently being constructed for the CW Argon Laser Doppler Tracking experiment. This system, which consists of a 10 watt continuous argon laser and a converted Nike Ajax pedestal is capable of ±1 minute tracking accuracy, and can transmit 4 watts at 4880Å in a beam width of 2/3 milliradian angular diameter. It was designed for and will be used to track the GEOS satellites.

The optical sensor will consist of a four inch diameter cylinder ten inches long which will enclose an optical filtering system, a photomultiplier, a photomultiplier power supply, and electronic circuits to process the photomultiplier output and convert it to a form compatible with the satellite telemetry input. The sensor requires an on-off command, and a telemetry channel of 80 Hz.

INTRODUCTION

The objective of the experiment is to determine whether laser beams transmitted to orbiting satellites arrive at the satellite at predicted power levels, and to determine the frequency and depth of modulation of scintillation of the laser beam as viewed from the satellite.

The concept of the experiment is shown in Figure A. An argon (4880Å) laser beam transmitted to the orbiting GEOS-B satellite by a ground tracking station is perturbed by the atmosphere and arrives at the satellite intensity modulated.

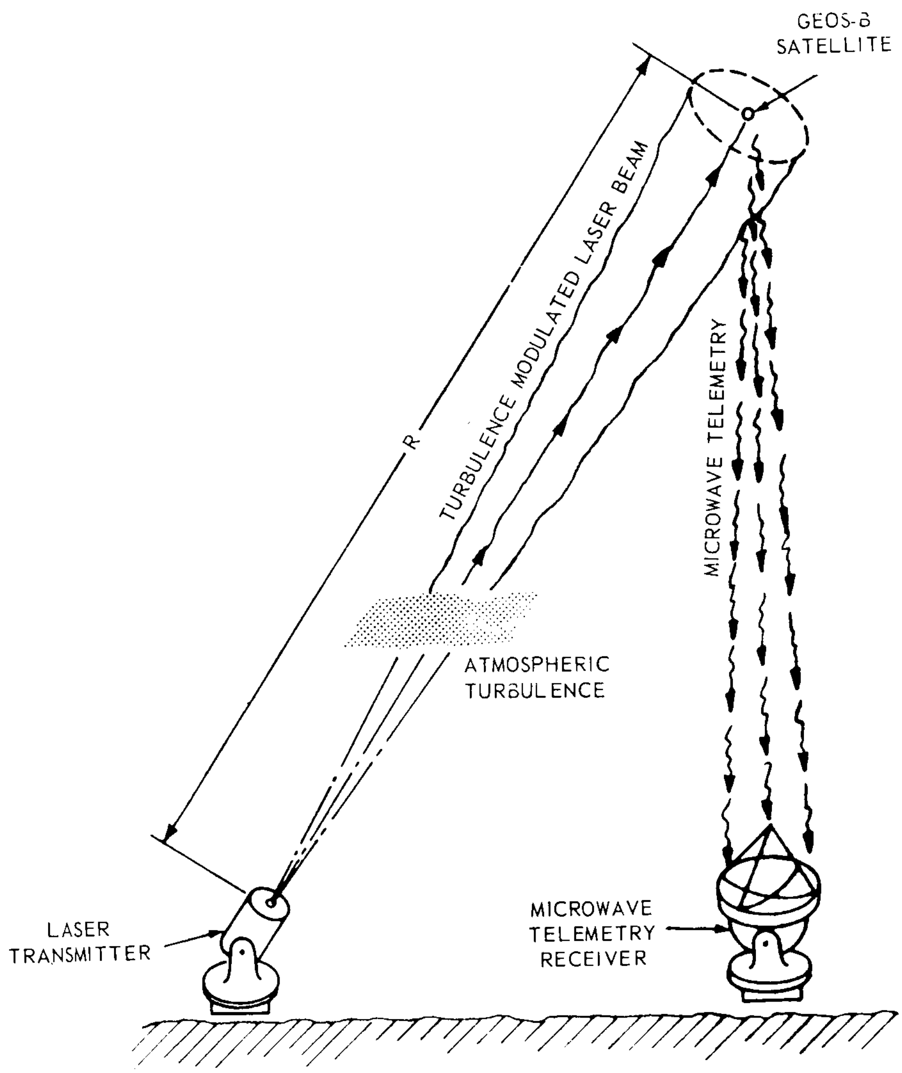


Figure A.

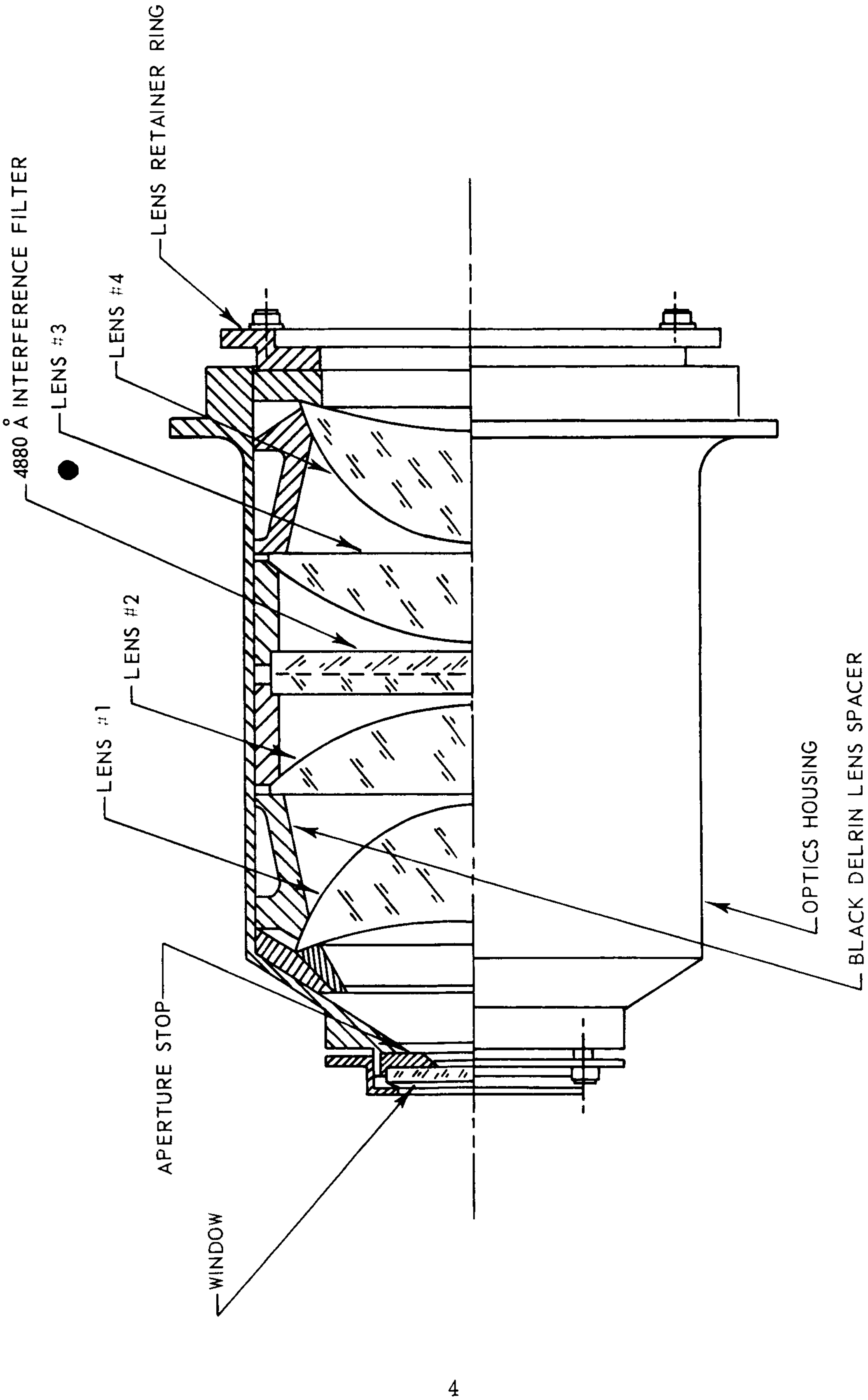

LENS RETAINER RING
4880 Å INTERFERENCE FILTER
LENS #4
LENS #3
LENS #2
LENS #1
APERTURE STOP
WINDOW
OPTICS HOUSING
BLACK DELRIN LENS SPACER

Figure 1.2-1

1. DESIGN OF THE LASER DETECTOR

1.1 Purpose

The function of the laser detector is to receive a laser signal from the ground transmitter, distinguish it from the earth background and convert it into an electrical signal compatible with the satellite telemetry system. Because the receiver cannot be directed toward the transmitter, it must have a field of view of 80 degrees, and must provide optical filtering. In order to reject DC background, the transmitted laser signal is modulated at 13,000 Hz, and the detector is tuned to this frequency. A logarithmic output is provided so that a three decade range of input powers (10^{-10} to 10^{-13} watts) can be accommodated within the -5 to +5 volt input of the satellite telemetry system.

1.2 Optical System

The optical system must separate the earth background radiation from the laser signal. Because an 80-degree field of view is required, the radiation passing through the aperture stop is first collimated so that it strikes the interference filter at nearly normal incidence, as required for proper filter selectivity. A cross section view of the optical system is shown in Figure 1.2-1. Light passing through the aperture stop is refracted by the first two lenses, and impinges on the interference filter within eight degrees of normal. Wavelengths within the filter passband proceed through the filter and are condensed onto the photomultiplier cathode by the final two lenses. The remainder of the radiation is either reflected or absorbed by the filter.

1.2.1 Lenses — There are four lenses, which constitute two identical 2.2 inch focal length f/0.78 objectives. All lenses are constructed of Corning #7940 UV grade fused silica, magnesium flouride coated for maximum transmission at 4880 Angstroms. Lenses #1 and #2, plus the 0.60 inch diameter aperture stop form a simple collimator which limits the total divergence of rays passing through the filter to sixteen degrees. Lenses #3 and #4 converge the radiation to form an image of the aperture stop on the photomultiplier cathode. The window is coated with a conductive coating of tin oxide on its exterior surface. This coating which has a transmission of better than 85 percent is grounded to the optical system housing to bleed off any static charges.

1.2.2 Interference Filter — The interference filter was obtained from Thin Film Products, Inc. in Cambridge, Massachusetts and is 2.70 inches in diameter. Peak transmission is approximately 50 percent at 4890 Angstroms with a half power bandwidth of 46 Angstroms. The peak of the passband shifts with the angle of incidence and changes to 4880 Angstroms for rays at an angle of

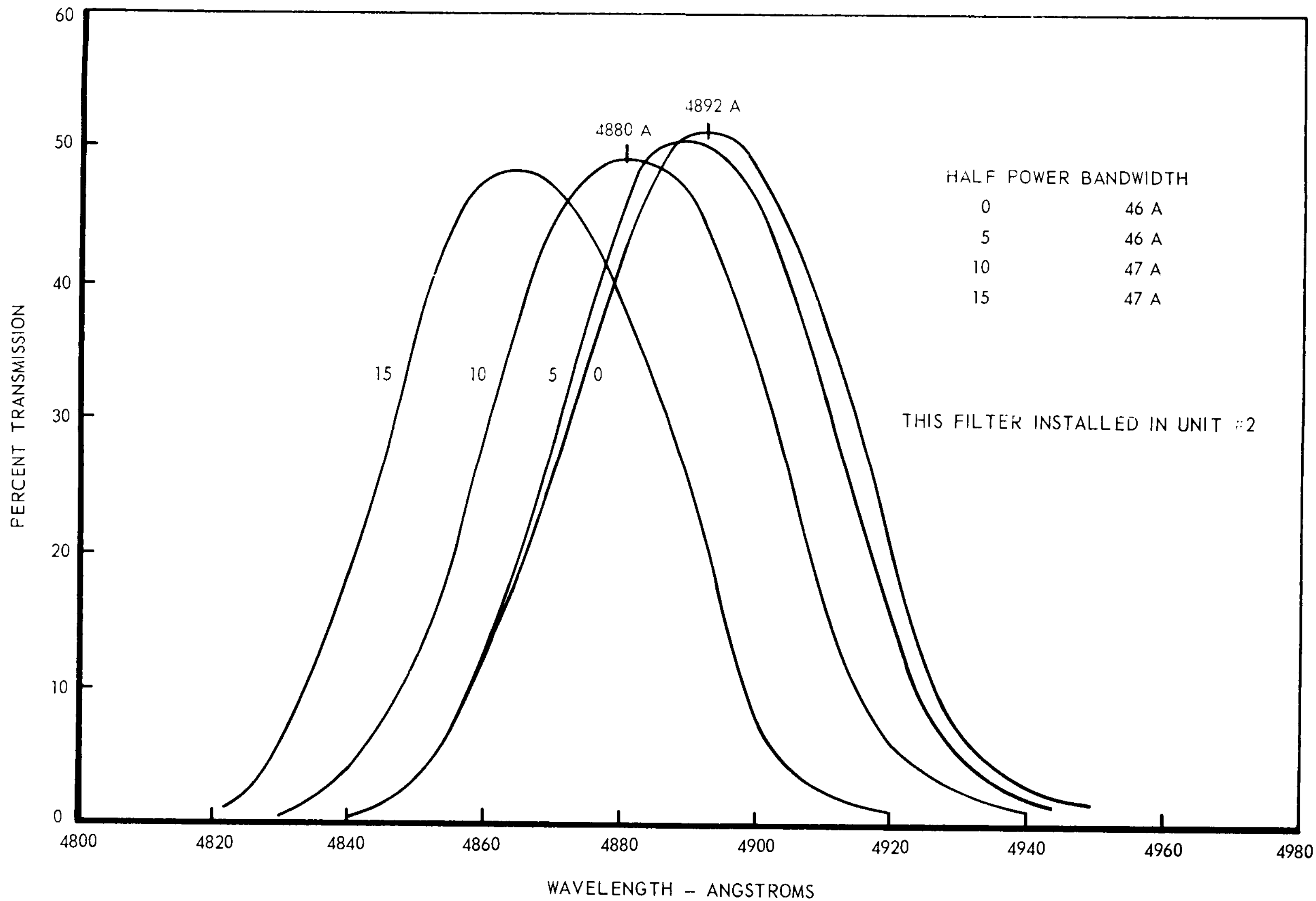


Figure 1.2.2-1. Spectral Transmission — T.F. Filter 5/3/67

incidence of 10 degrees. Figures 1.2.2 - 1 and 1.2.2 - 2 illustrate the characteristics of the filter installed in detector unit #2. The curves are typical of units #2, #3, and #4. Outside this passband, filters are blocked to less than 0.0063 percent from 2500 to 20,000 Angstroms. The substrate is Corning #7940 Industrial Grade fused silica. Surfaces are not anti-reflection coated.

1.2.3 Optical System Hardware — The optical system is mounted in a type 2024 - T4 aluminum alloy housing. This housing, and all other aluminum parts are irridited as per MIL - C - 5541 to provide an electrically conductive coating. Black Delrin spacers are used to support and separate the optical elements. The spacers and optical elements are stacked inside the housing and held in place by a lens retainer ring. All parts of the optical system are baked in a thermal vacuum oven for several hours before assembly to insure that all parts are clean, and fully outgassed.

1.3 Photoelectric Sensor

The sensor is an Integrated Photoelectric Sensor (IPS) produced by the Photoelectric Division of Electro-Mechanical Research Inc. It consists of an ASCOP Model 541 D-01-14 multiplier phototube packaged integrally with a high voltage power supply Model 652. A D type bi-alkali photocathode was chosen, in preference to cathode materials of higher quantum efficiency, due to its excellent quantum efficiency stability. Specification Sheets 1.3-1 and 1.3-2 describe the characteristics of the sensor. Gain of the phototube is adjusted by varying the trimming resistor of the integrated power supply.

1.4 Signal Processing System

A block diagram, and simplified circuit diagram are shown in Figures 1.4-1 and 1.4-2. The function of the signal processing system is to convert the incoming signal power so that

$$V_o = 3.33 \log \frac{P_{in}}{P_{min}} - 5 \text{ volts}$$

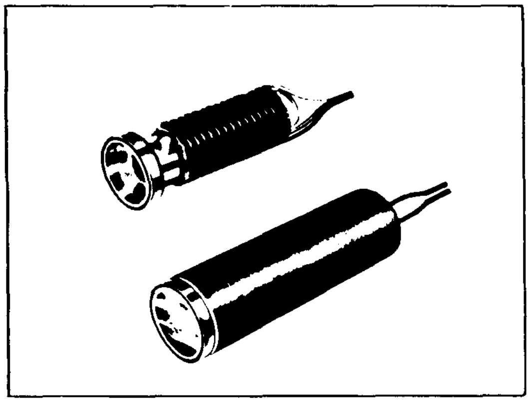
where V_o = output voltage

P_{in} = instantaneous peak optical power in received 13,000 Hz laser signal

P_{min} = reference power level = 10^{-13} watts

SPECIFICATION
No. 541D0114F074

SPECIFICATION DATA



MULTIPLIER
PHOTOTUBE
MODEL 541D-01-14

GENERAL

The EMR Model 541D-01-14 Multiplier Phototube is a 14-stage, end-on-window tube with a one-inch-diameter, semitransparent bi-alkali photocathode. This rugged tube is sensitive to light in the visible spectrum, with peak sensitivity in the blue region. Primarily designed for high-stability operation at elevated temperatures (to +150°C), the tube is particularly suited for use at and below room temperature, where extremely low dark current is a prime consideration.

PERFORMANCE

The one-inch-diameter useful cathode of the Model 541D-01-14 has a typical quantum efficiency of 6% at 4100A and a typical room-temperature anode dark current of 3×10^{-11} ampere at a multiplier gain of 10^6. This dark current is approximately two orders of magnitude less than that of Sb-Cs tubes. The dark current at +150°C is comparable to that of Sb-Cs tubes at +75°C. Using a unique design of venetian-blind dynodes and hard-glass Kovar ring construction in an encapsulated package, the tube is capable of withstanding 100g shocks of 11-millisecond duration.

Interstage resistors are potted with the tube in a fiberglass housing 4 ¼ inches long and 1 ¼ inches in diameter. These resistors are welded to the Kovar rings prior to potting; this eliminates insulation problems and results in a resistor-chain mounting that is as

PRINCETON DIVISION EMR

Specification Sheet 1.3 - 1a

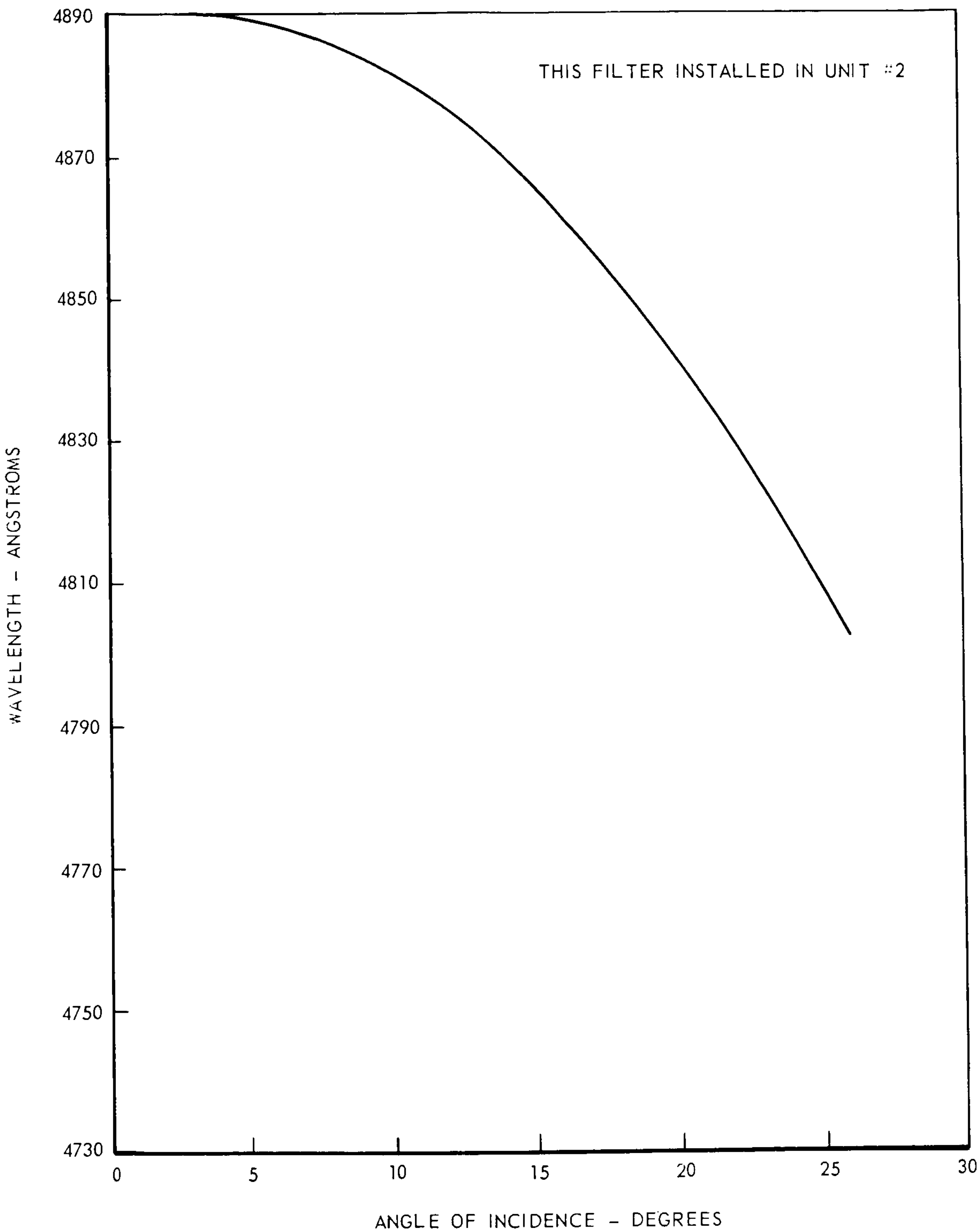


Figure 1.2.2-2. Peak Transmission Wavelength vs Angle of Incidence — T.F. Filter 5/3/67

	Min.	Typical	Max.	Unit
Equivalent Noise Input at +20°C and Current Amplification of 10^6:				
Luminous (ϵ_N)		2.0×10^{-13}		lm
Radiant (ϵ_N) at 4100A . . .		1.5×10^{-16}	4.0×10^{-16}	w
Supply Voltage:			3600	v
Anode Current:			0.3	ma
Ambient Temperature:			+150	°C

ENVIRONMENTAL SPECIFICATIONS

Shock: 100g, 11-millisecond duration.

Vibration: 30g, 20 to 3000 cps.

Temperature: −55°C to +150°C.

EMR warrants each tube for all of the characteristics identified in these specifications. However, EMR will not restock or give any financial consideration on tubes which meet these specifications but do not perform in accordance with uncontrolled characteristics which are unique to a specific customer. If control of special characteristics is desired, specific agreement regarding these characteristics must be achieved prior to acknowledgment of an order.

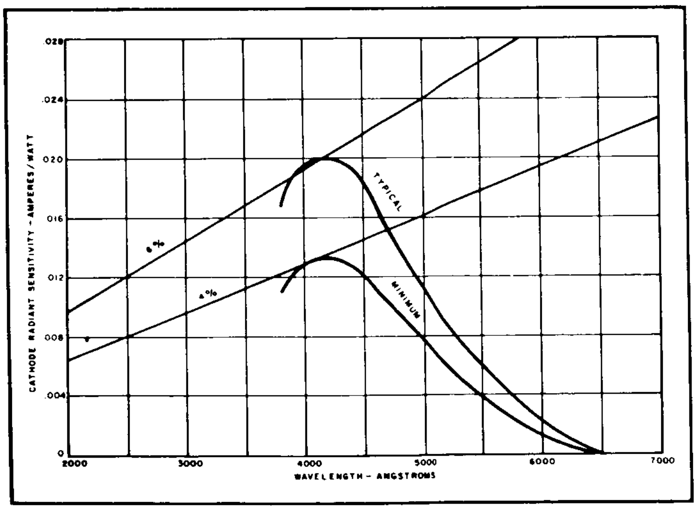


FIGURE 1 SPECTRAL RESPONSE CHARACTERISTICS

The cathode radiant sensitivity in amperes per watt as a function of wavelength in angstroms is given for the typical and minimum tube sensitivities. Superimposed are constant-quantum-efficiency lines of 6% and 4%, corresponding to the performance at 4100A for the typical and minimum curves, respectively.

rugged as the tube itself. Unless specified otherwise, 3.9-megohm resistors are used and the phototube is supplied as a potted assembly from which three color-coded leads are brought out.

PHYSICAL CHARACTERISTICS

Number of Dynodes: 14.

Dynode Type: Venetian-blind; Ag-Mg.

Maximum Overall Length (Unpotted): 3.94 inches (10 cm).

Typical Weight (Unpotted): 71 gm.

Window Material: 7056 glass.

Cathode Sensitive Area: 0.785 sq. in. (1" diameter).

Cathode Type: Semitransparent bi-alkali.

PACKAGING

Housing: Normally packaged in a fiberglass housing 1 ¼" OD by 4 ¼ long. (See Figure 4.)

Typical Weight (Potted): 140 gm.

ELECTRICAL CHARACTERISTICS

	Min.	Typical	Max.	Unit
Quantum Efficiency (Q) at 4100A:	4	6		%
Cathode Luminous Sensitivity (s_k):		15		μa/lm
Cathode Radiant Sensitivity (σ_k) at 4100A:	0.013	0.020		a/w
Voltage Required for Current Amplification (G) of 10^5:		1950	2300	v
10^6:		2600	3000	v
5×10^6:		3200	3600	v
10^7:		3450		v
Dark Current (i_D) at +20°C and Current Amplification of 10^5:		3.0×10^{-12}		a
10^6:		3.0×10^{-11}	1.0×10^{-10}	a
5×10^6:		1.5×10^{-10}		a
10^7:		3.0×10^{-10}		a
Anode Luminous Sensitivity (S) at Current Amplification of 10^6:		15		a/lm
Anode Radiant Sensitivity (σ) at 4100A and Current Amplification of 10^6:	13,000	20,000		a/w
Equivalent Anode Dark-Current Input at +20°C and Current Amplification of 10^6:				
Luminous (E_D)		2.0×10^{-12}		lm
Radiant (ϵ_D) at 4100A . . .		1.5×10^{-15}	8.0×10^{-15}	w

September 30, 1966

MODEL 601E

INTEGRATED PHOTOELECTRIC SENSOR

TENTATIVE SPECIFICATIONS

1.0 GENERAL DESCRIPTION

This specification describes an Integrated Photoelectric Sensor (IPS) consisting of an ASCOP Multiplier Phototube, Model 541 or Model 542, packaged integrally with a high voltage power supply Model 652E.

Static adjustment of the phototube current gain is effected by means of a selectable external resistor. The adjustment range is sufficient to vary this gain by from 2 to 3 orders of magnitude dependent upon tube type.

The Model 652E Power Supply, used in this device, is similar to the Model 652A wrap around power supply with a greater adjustment range (1750 to 3500 V) and with the added feature of short circuit and overload protection.

The device uses exclusively solid-state components and its rugged mechanical design lends itself to space research employment.

2.0 ELECTRICAL SPECIFICATIONS

2.1 PHOTOTUBE SPECIFICATIONS

2.1.1 Refer to tube type for photocathode characteristics, Multiplier Phototube Characteristics and Maximum Ratings.

2.1.2 Sensitivity: As determined by Phototube Specification, data sheet and applied voltage.

2.1.3 Temperature Stability: Refer to tube type for temperature stability. High voltage applied to tube varies approximately ±.03%/°C average over operating range.

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Specification Sheet 1.3 - 2a

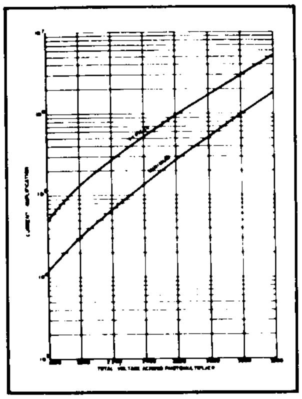

FIGURE 2
CURRENT AMPLIFICATION

The dependence of current amplification on voltage supplied between photocathode and anode. Curves are given for typical and minimum tube performance.

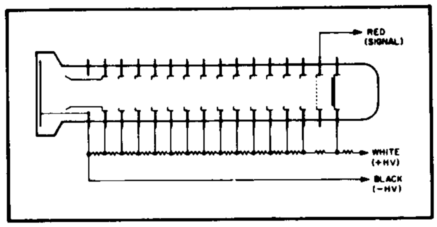

FIGURE 3 SCHEMATIC DIAGRAM

Resistor values are equal throughout.

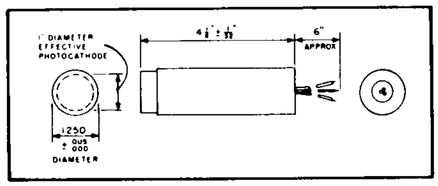

FIGURE 4 OUTLINE DRAWING

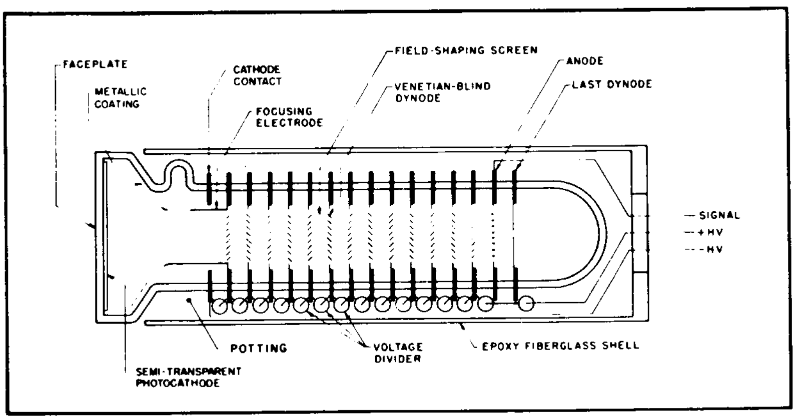

FIGURE 5 FUNCTIONAL DIAGRAM

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Model 601E
Integrated Photoelectric Sensor
Tentative Specifications

September 30, 1966

5.0 MECHANICAL SPECIFICATIONS

5.1 IPS Package Dimensions: See drawing for outline dimensions.

5.2 Weight: Less than 16 ounces

5.3 Connections: See outline drawing--six 12 inch long leads: RG-196/U anode lead and five #22 stranded, teflon insulated leads. Upon request, other insulated wire may be provided.

5.4 Housing Material: Stainless steel

6.0 ENVIRONMENTAL SPECIFICATIONS (OPERATIONAL)

6.1 Temperature: -10°C to 65°C

6.2 Vibration: 30 g, 20 to 3000 cps

6.3 Shock: 50 g, 11 millisecond duration

6.4 Altitude: Earth's surface and space environment

7.0 ENVIRONMENTAL SPECIFICATIONS (NON-OPERATIONAL)

7.1 Temperature: 55°C to 70°C

8.0 ORDERING INFORMATION

Specify as: 601E-(_______a_________)

in place of (a): Insert any 14-stage tube in the 541 or 542 series, for example, (541A-01-14-03900).

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Specification Sheet 1.3 - 2c

2.1.4 Anode Noise induced by high voltage power supply: bipolar differentiated pulse of 5 mv P-P across an anode load resistor of 100 K shunted by 100 pf, occuring at between 2 and 3 K cps.

2.2 POWER SUPPLY

2.2.1 Input

(a) Voltage: 28 volts ±3 volts
(b) Power: 700 mw max. at nominal input max. output of 263 mw delivered to phototube and bleeder combination.

2.2.2 Output

(a) Voltage Range: 1750 to 3500 volts at 75 μa max. Adjusted externally with a trimming resistor (short circuit to 150 K) connected between gain adjust lead and 28 volt return. For optimum temperature stability use 500 ppm T.C. resistor and mount so that its temperature will approximately duplicate that of the electronics. Refer to fig. 1 for typical Voltage Output vs. Trimming Resistance Curve.
(b) Line Regulation: ±.002%
(c) High voltage monitor: The high voltage applied across the phototube may be monitored by measuring the dynode bleeder current or by measuring the voltage across a precision resistor inserted between the dynode bleeder string lead and ground. For either method, when the anode current is much less than the bleeder current, the high voltage is proportional to the total dynode bleeder resistance. When anode current is commensurate with bleeder current, these outputs cannot be correlated with tube voltage.
(d) High voltage ripple: Less than 150 mv P-P at max. output

2.3 GROUNDING

28 V return, dynode bleeder string, high voltage return, anode shield and metal shell isolated. For proper operation all leads should be connected to ground externally. High voltage supply designed for negative output (connected internally to cathode). Anode load resistor should be terminated to ground externally.

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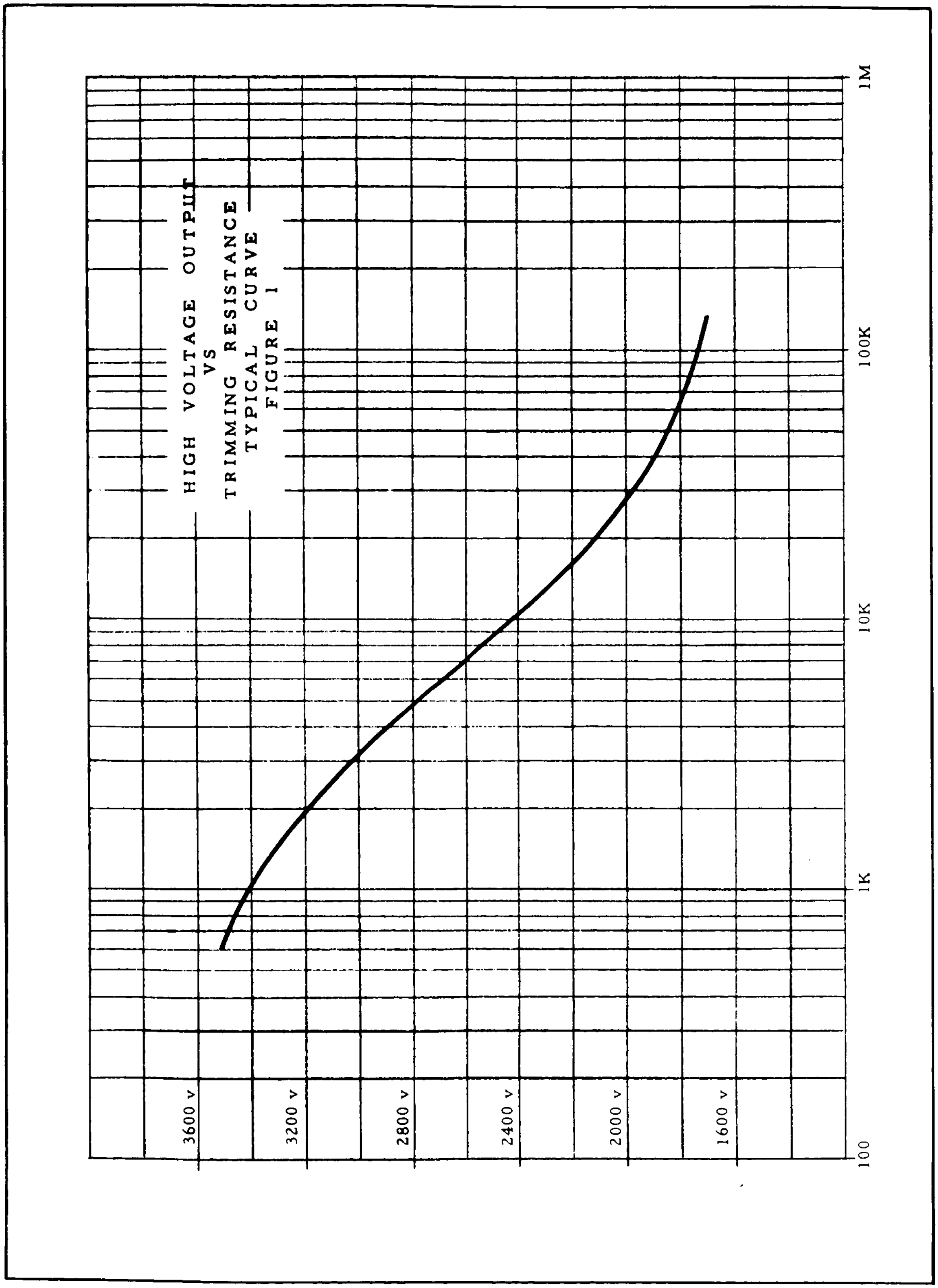
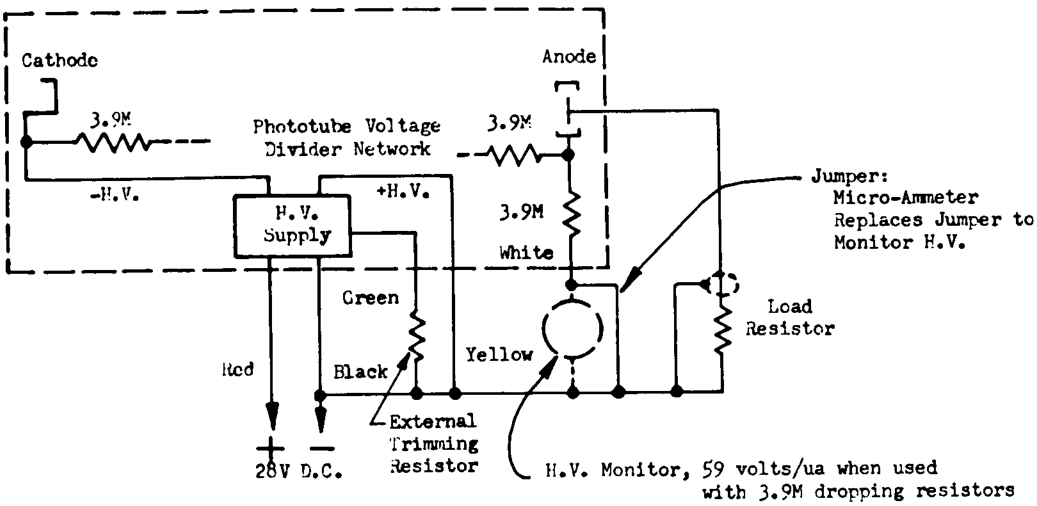
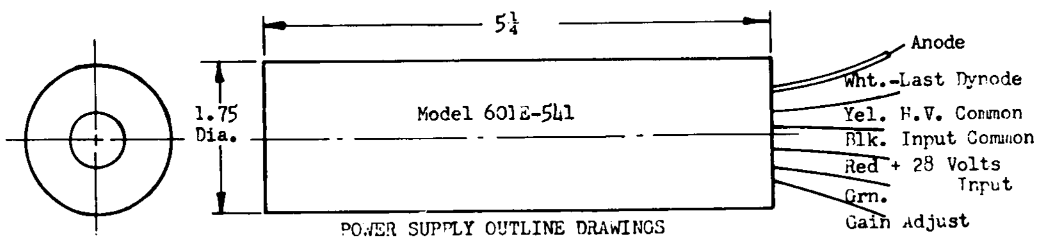
Specification Sheet 1.3 - 2b



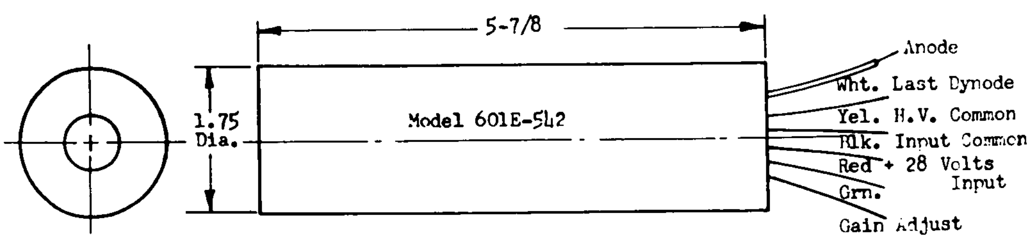
Specification Sheet 1.3 - 2e



POWER SUPPLY SCHEMATIC



POWER SUPPLY OUTLINE DRAWINGS



Specification Sheet 1.3 - 2d

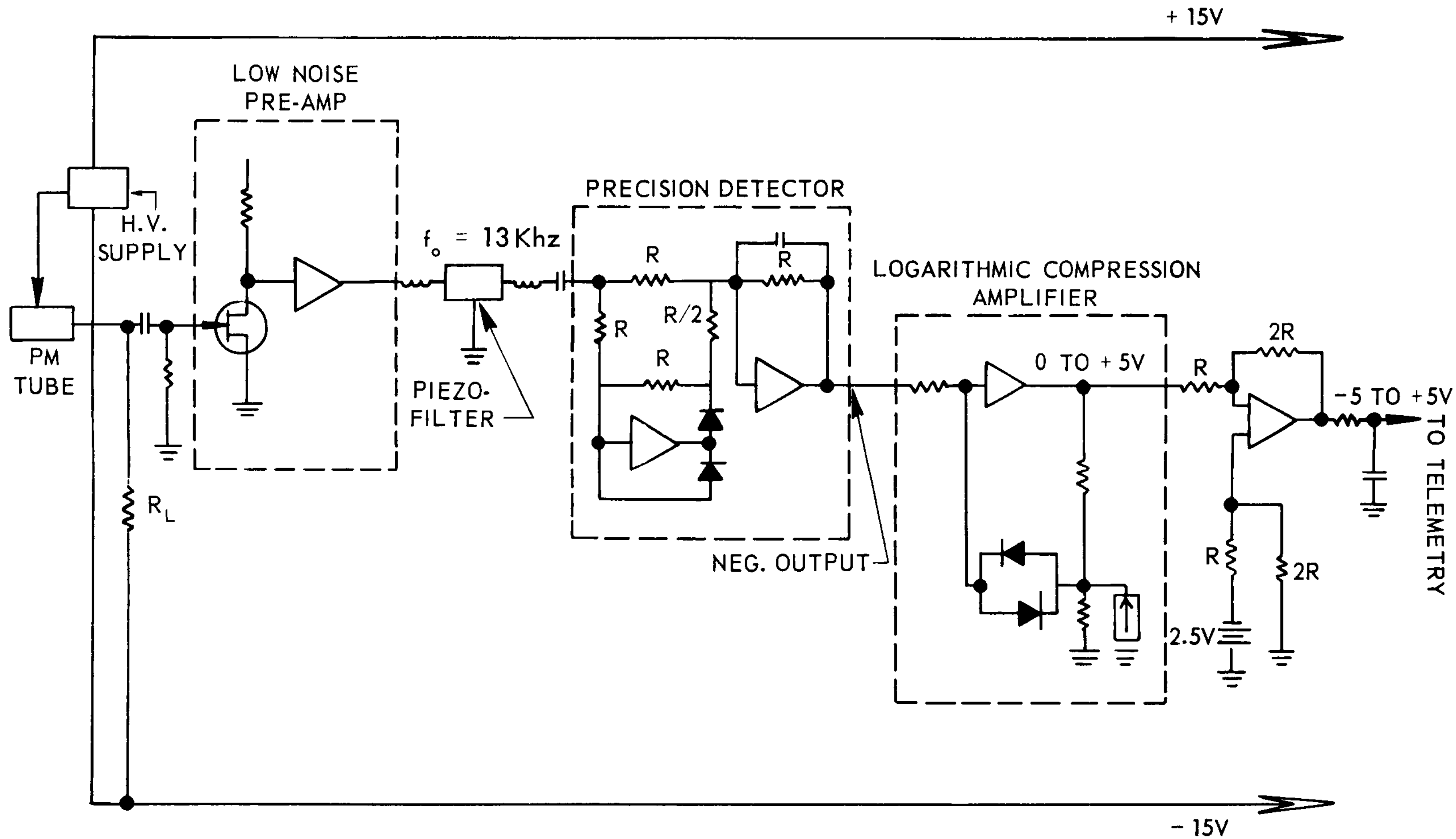


Figure 1.4.2. Signal Processing System

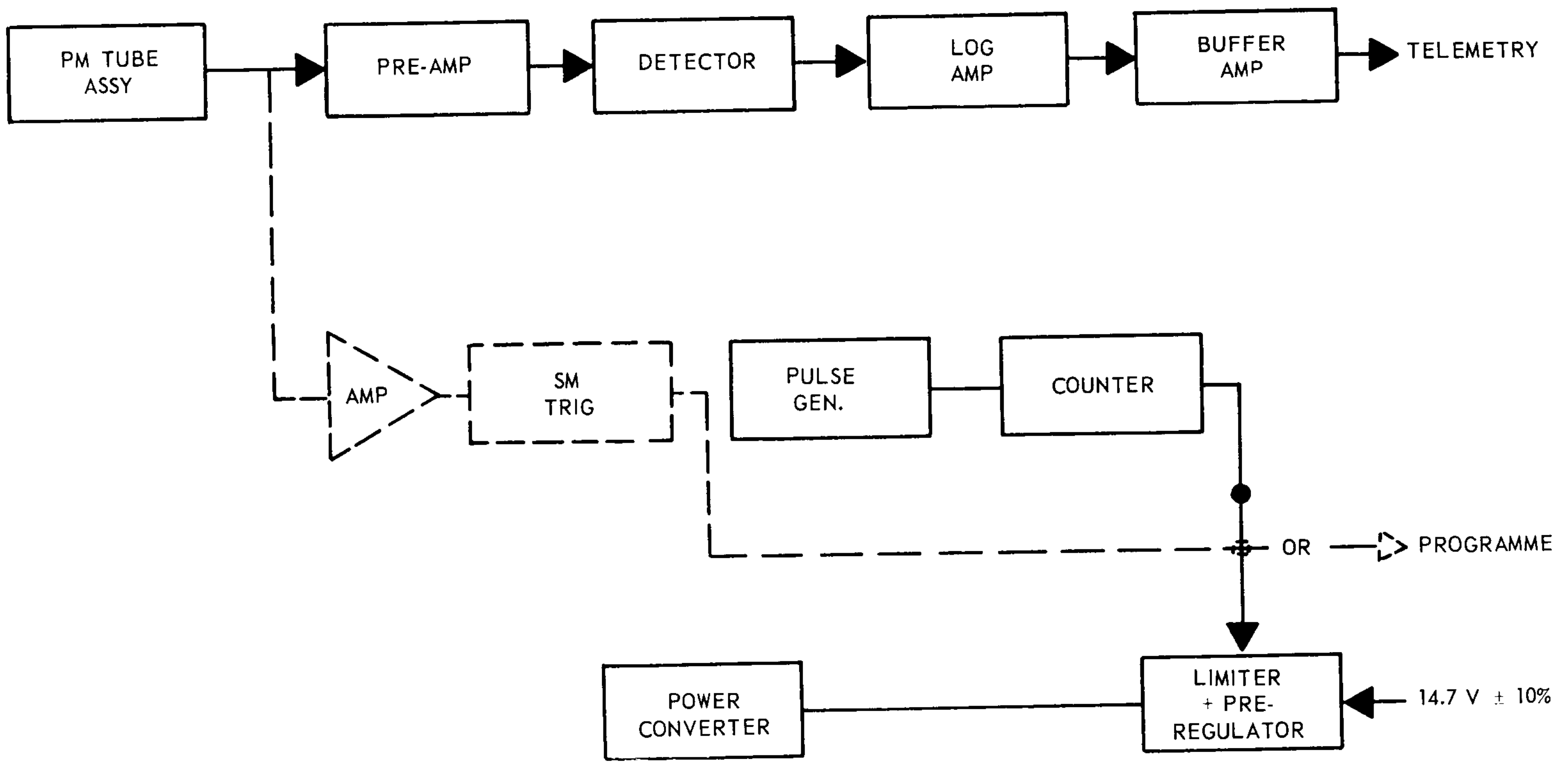


Figure 1.4.1. Block Diagram of System

first amplifier. The capacitor across the feedback resistor of the second amplifier provides an effective low pass filter.

1.4.4 Logarithmic Compression Amplifier — The output of the detector is fed into a log compression amplifier. This is a standard operational amplifier with a log feedback element consisting of a diode and some additional circuits to regulate the current through the diode to set the range and linearity. The response is from DC to 80 hertz, and the amplifier handles signals of only one polarity. An additional diode (shown in the feedback circuit) is used to prevent the amplifier from latching up in saturation.

1.4.5 Buffer and Level Shifting Amplifier — The output of the log amplifier is fed into a buffer and level shifting amplifier. This is a simple differential amp where the non-inverting input is used to translate the output from 0 - 10 V to -5 to +5 volts. The amplifier has a gain of two and a resistor has been put in series with the output to prevent a short circuit from damaging the buffer amp.

1.4.6 DC to DC Converter — As can be seen from Figures 1.4.6-1, the DC to DC converter is extremely simple. It consists of a toroidal transformer driven by 2 silicon transistors. The system is self oscillatory between 2 to 3 kilohertz and will start and operate over a wide temperature range.

The secondary voltages are rectified and filtered but not regulated. There is no need for regulation because the primary voltage is regulated and in addition the differential amplifiers used in processing the signal are relatively insensitive to power supply variations.

1.4.7 Preregulator and Limiter — Figure 1.4.7-1 shows the preregulator and limiter. The circuit consists of series regulator, a reference, and a difference amplifier. In addition, it has a current regulator and a silicon controlled switch. The preregulator is a straight forward design in which the output of the regulator is compared with a zener reference and the difference is fed back to the base of the series transistor. By properly selecting the resistor divider at the base of the difference amplifier the output voltage of the regulator can be set. The current limiter senses the system current through a series resistor and the limiter will pull the base of the series regulator toward ground when the current exceeds a preset limit which depends on the circuit values selected.

The silicon controlled switch is shown here to indicate a means of turning the experiment off upon a signal received from the timer. A signal from the timer will fire the SCR, connecting the base of the series transistor to ground. The output of the regulator is thus reduced to zero.

The system works in the following manner:

1. The 13 Khz optical signal is received by the PM tube and converted into a 13 Khz electrical signal.

2. DC components are blocked by a capacitor, and AC components amplified by a preamplifier.

3. Output of the preamp is filtered by a 160 Hz bandpass filter centered on 13 Khz.

4. The modulation present on the 13 Khz carrier is detected by a detector.

5. A log amplifier compresses the 10^3 range of signals to a 10 volt change in output voltage.

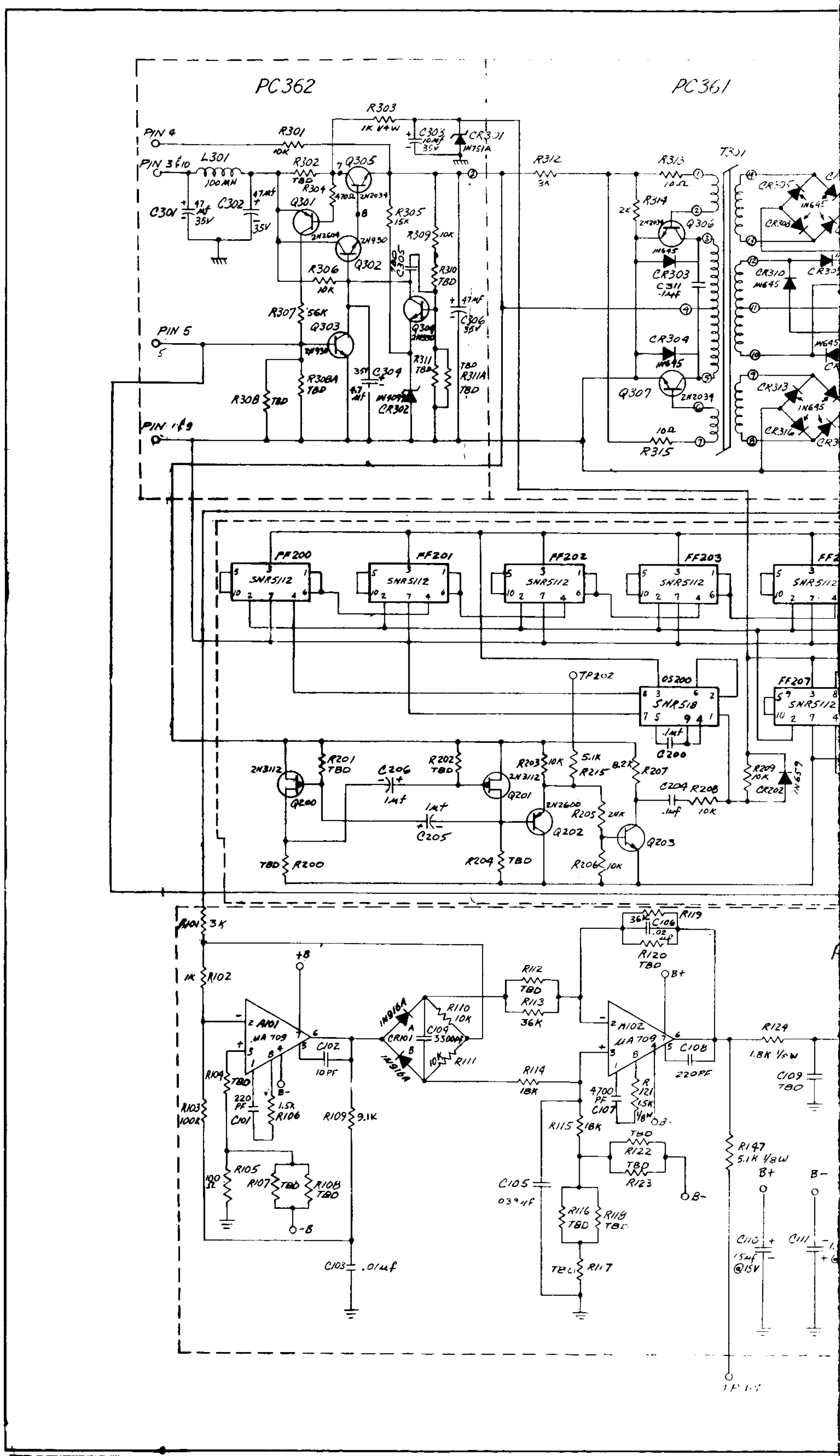
6. A buffer amplifier biases the 0 to +10 output voltage of the logarithmic amplifier to -5 to +5 volts, and interfaces with the satellite telemetry input.

A complete circuit diagram is shown in Figure 1.4-3.

1.4.1 Low Noise Preamplifier — The output of the PM tube is fed into a low noise field effect transistor. Because of the extremely high input impedance of the FET there is no loading due to the preamp, and R_L is the only load to the PM tube. The FET is followed by additional amplification to assure that the signal level is of sufficient amplitude to be compatible with the rest of the circuit.

1.4.2 Piezoelectric Filter — The output of the preamp is fed to a 13 kilohertz crystal filter with a 3 db bandwidth of 160 hertz. The input and the output of the filter have small series inductors to adjust the bandwidth.

1.4.3 Precision Detector — The output of the filter is fed to a precision detector. The low voltage signals (as small as one millivolt) require a far more sophisticated approach than a simple diode. Operation of the detector circuit employs diodes within the feedback loop of a high gain amplifier which renders the diodes effectively ideal. When the input voltage goes positive the output of the first amplifier goes negative by one diode drop, shutting off the upper diode, and bounding the amplifier through the lower diode. The second amplifier simply inverts the positive input voltage. When the input is negative, both amplifiers invert and the output is $e_{in} - 2e_{in} = {}^{-}e_{in}$, by virtue of the gain of two in the



PC362
PC361
PIN 4
PIN 3 & 10
PIN 5
PIN 1 & 9
R303
1K 1/4W
C303
CR301
1N751A
R301
10K
L301
100MH
R302
TBD
R304
470Ω
Q305
2N2039
Q301
2N2604
Q302
2N930
R305
15K
R309
10K
R310
TBD
C301
C302
47mf
35V
R306
10K
R307
56K
Q303
2N930
C304
CR302
Q304
R311
TBD
R311A
TBD
C306
47mf
35V
R308A
TBD
R308
TBD
R312
3K
R313
10Ω
T301
R314
Q306
CR303
C311
.1mf
CR304
Q307
2N2039
R315
10Ω
CR305
CR308
CR309
CR310
CR313
CR316
1N645
FF200
FF201
FF202
FF203
SNR5112
TP202
OS200
SNR518
FF207
C200
.1mf
2N3112
Q200
R201
TBD
C206
1mf
R202
TBD
Q201
R203
10K
R215
5.1K
R207
8.2K
C204
.1mf
R208
10K
R209
10K
CR202
1N659
C205
1mf
Q202
2N2600
R205
24K
Q203
R200
TBD
R204
TBD
R206
10K
R101
3K
R102
1K
+B
A101
μA 709
R104
TBD
C101
220 PF
R106
1.5K
C102
10 PF
R103
100K
R105
100Ω
R107
TBD
R108
TBD
-B
R109
9.1K
C103
.01uf
CR101
1N916A
R110
10K
C109
3300PF
R111
10K
R112
TBD
R113
36K
R114
18K
C106
.02uf
R119
36K
R120
TBD
B+
A102
μA 709
C108
220PF
C107
4700 PF
R121
15K
1/8W
B-
R115
18K
R122
TBD
R123
TBD
C105
.039uf
R116
TBD
R118
TBD
R117
TBD
R124
1.8K 1/8W
C109
TBD
R147
5.1K 1/8W
C110
15uf
@15V
C111

21 A

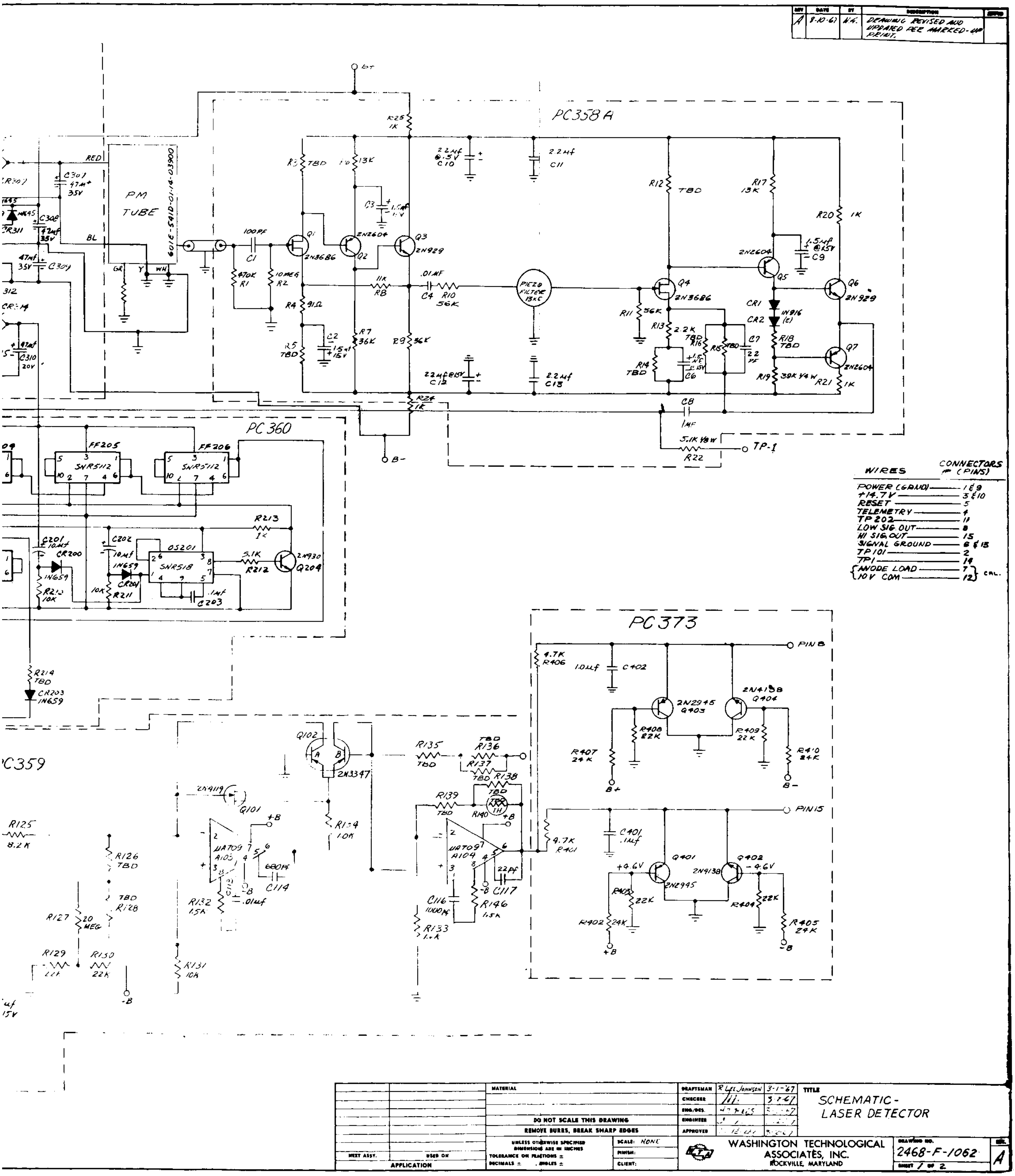

PC358 A
PM TUBE
PIEZO FILTER
PC 360
PC 373
PC359
WIRES
CONNECTORS (PINS)
POWER (GRND) 1 & 9
+14.7V 3 & 10
RESET 5
TELEMETRY 4
TP 202 11
LOW SIG OUT 8
HI SIG OUT 15
SIGNAL GROUND 6 & 13
TP101 2
TP1 14
ANODE LOAD 7
10 V COM 12
DRAWING REVISED AND UPDATED PER MARKED-UP PRINT.
DO NOT SCALE THIS DRAWING
REMOVE BURRS, BREAK SHARP EDGES
SCHEMATIC - LASER DETECTOR
WASHINGTON TECHNOLOGICAL ASSOCIATES, INC.
ROCKVILLE, MARYLAND
2468-F-1062
A

Figure 1.4 – 3.

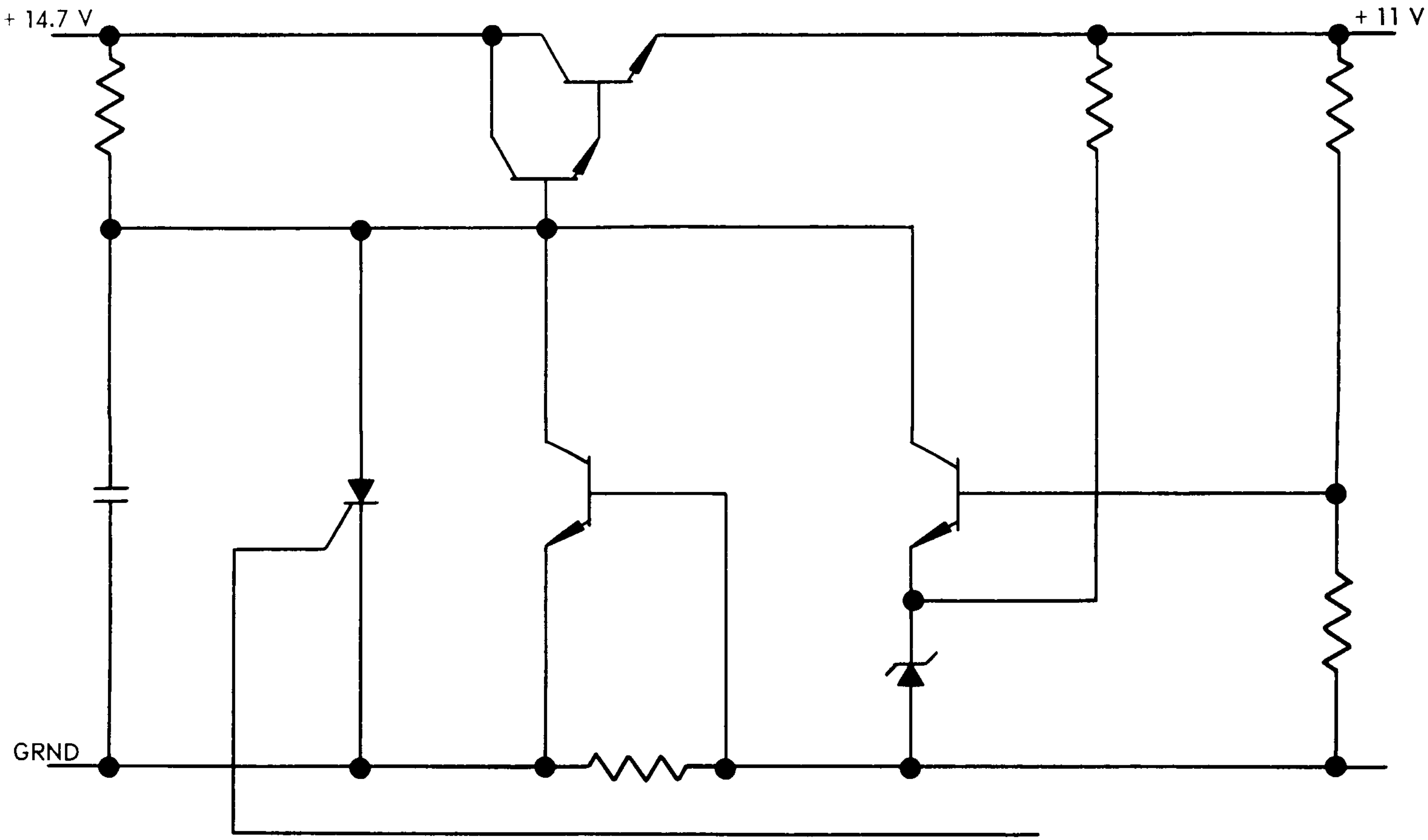


Figure 1.4.7-1. Pre Regulator and Limiter

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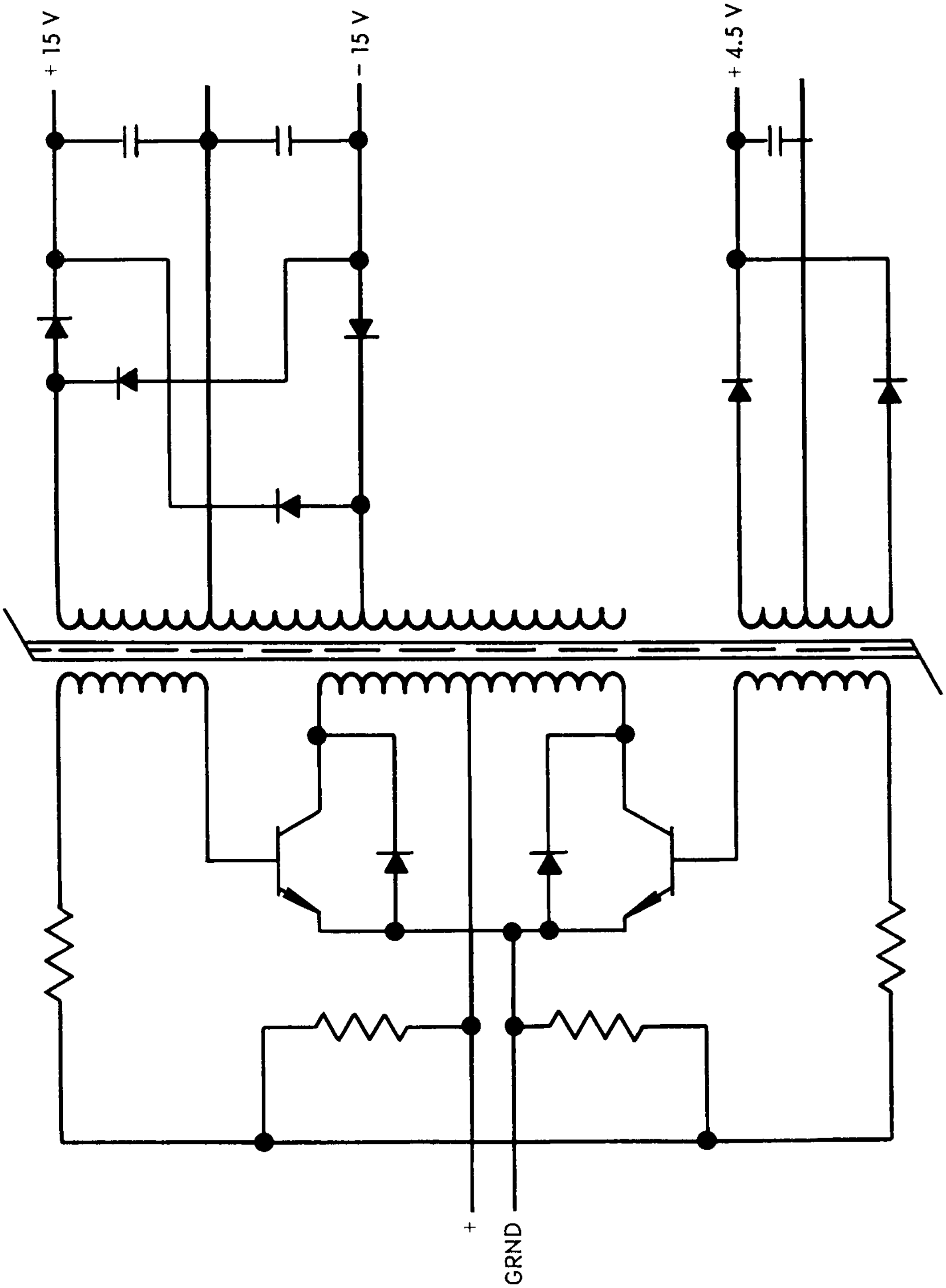

Figure 1.4.6-1. DC To DC Converter

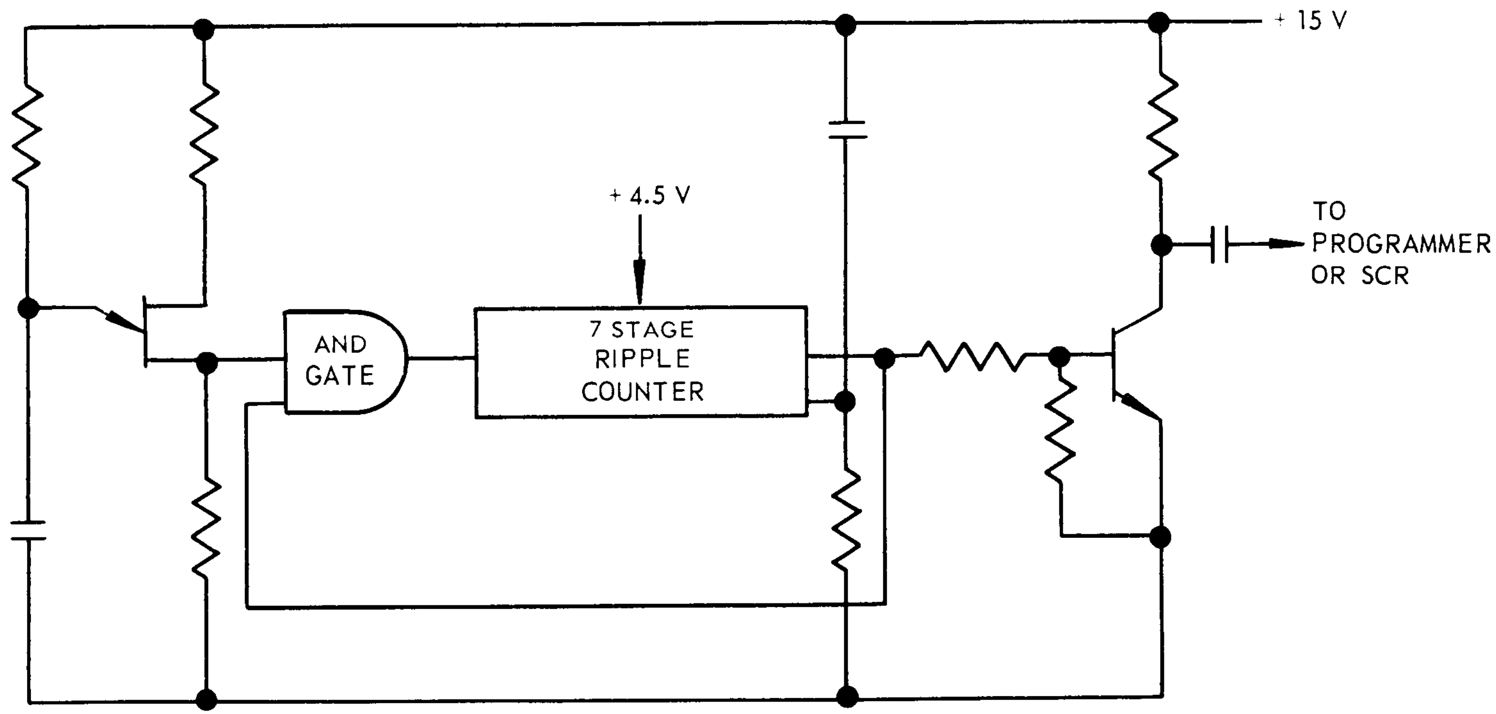

Figure 1.4.8-1. Power Turnoff Timer

1.4.8 Back-Up Shut Down System — The back-up timer is used to assure that the laser detection is turned off after approximately 15 minutes. It is intended that the ground station supply a turn-off command. When this is either forgotten or for any reason the satellite is out of the command transmitter range, the back-up system will assure that the PM tube assembly is never subjected to the bright sunlit earth with the high voltage power supply on. A back-up timer is shown in Figure 1.4.8-1. It consists of a unijunction relaxation oscillator with a period of approximately 7 seconds. The output of the oscillator is fed into two input "AND" gates. The output of the gate feeds a divider and the divider supplies an output for every 128 input pulses. This amounts to 7 sec. $\times$ 128 = 896 sec. or 15 minutes. The output also feeds the second input of the "AND" gate and inhibits the output of the gate when the division has been completed. To make this system successful it must be guaranteed that the divider is properly set. A resistor-capacitor network connected to the preset inputs of the SNR5112 makes sure that upon application of the power to the system all counter stages are in the reset state. Proper logic is supplied to prevent the SCR in the limiter from misfiring when power is turned on. The 7 second period was selected because it is felt that any timing circuit with a period exceeding 10 sec. becomes unreliable as far as the period is concerned.

1.4.9 Input-Output Wiring — Power input, and signal outputs as well as several test points are connected to the satellite through a 15 wire lead. A Cannon type DAM-15P-NMB plug terminates this lead, and mates with a type DAM 15S-NMB plug on the satellite. Functions of the fifteen pins of the connector are listed in Table 1.4.9. In addition to the 15 leads, the case of the detector is grounded to the satellite frame. Pins 7 and 12 are used only during the initial testing of the unit, and must be shorted during operation of the unit.

1.5 Mechanical Configuration

The laser detector is housed in a type 2024-T4 irridited aluminum alloy case. Overall dimensions are 11 $\times$ 4-3/32 $\times$ 4-1/16. Total weight is 4.194 lbs. Stainless steel bolts in locking Heli-Coil inserts are used to fasten the various parts together. Dimensions of the detector are shown in Figure 1.5.

2. PERFORMANCE TESTS

2.1 Optical System

2.1.1 Spectral Transmission of Optical System — A test of the spectral transmission was performed using a Bausch & Lomb monochrometer (Serial No. 20773). Figure 2.1.1-1 illustrates the test setup. The exit pupil of the

Table 1.4.9

Pin Functions For Input/Output Connector

PIN NUMBER	FUNCTION
1 & 9	Power Ground
3 & 10	+14.7 Volts
8	30 Hz Signal Out
15	80 Hz Signal Out
7*	Bottom of Anode Load
12*	Ground
6 & 13	Signal Ground
11	Test Point 202 (Clock)
2	Test Point 101
14	Test Point 1 (Preamp Output)
4	Telemetry
5	Reset

*Pins 7 and 12 must be shorted for operation of detector

monochrometer (slits set at 0.25 $\times$ 10 mm) was imaged on the entrance pupil of the detector lens system. A photomultiplier was placed behind the lens system to detect radiation transmitted through the lens system. Readings of transmitted light were taken every 10 Angstroms from 4800 to 4950 Angstroms. The detector lens system was then removed, and readings at the same wavelengths were taken with the photomultiplier in the plane of the image of the monochrometer slit. Ratios of the two readings gave the transmission values. The spectral resolution of the B&L monochrometer is shown in Figure 2.1.1-2. Table 2.1.1 is a listing of results, and Figures 2.1.1-3 through 2.1.1-6 are graphical curves of the spectral transmission.

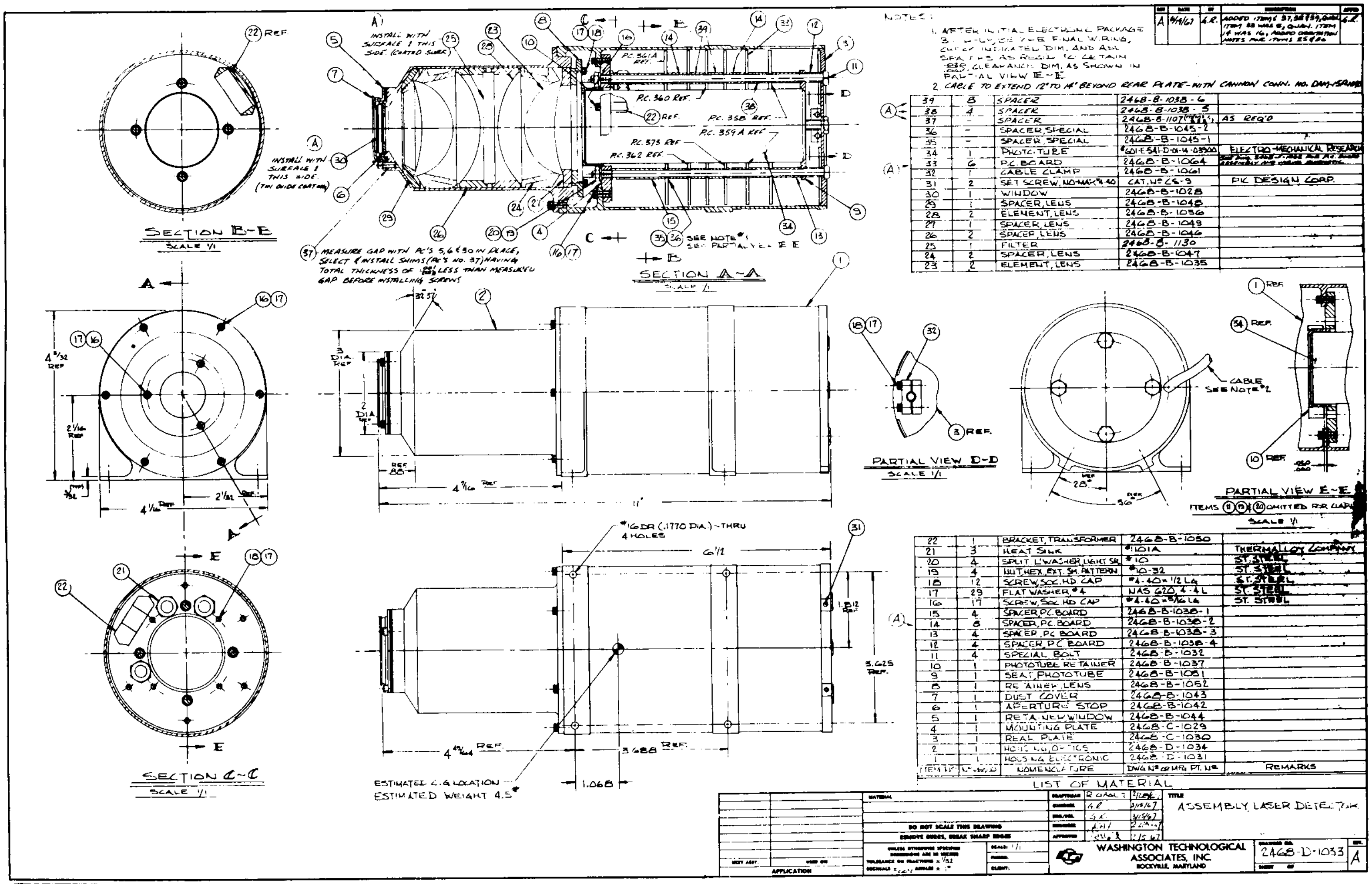
SECTION B-B
SCALE 1/1
SECTION A-A
SCALE 1/1
SECTION C-C
SCALE 1/1
PARTIAL VIEW D-D
SCALE 1/1
PARTIAL VIEW E-E
SCALE 1/1
CABLE SEE NOTE 2
ESTIMATED C.G. LOCATION
ESTIMATED WEIGHT 4.5#
LIST OF MATERIAL
ASSEMBLY, LASER DETECTOR
WASHINGTON TECHNOLOGICAL ASSOCIATES, INC.
ROCKVILLE, MARYLAND
2468-D-1033

Figure 1.5

Table 2.1.1

Spectral Transmission of Laser Detector Optical Systems

at 0° Incidence

Wavelength (Angstroms)	Transmission (%)			
	Unit #1	Unit #2	Unit #3	Unit #4
4800	0.7	0.0	00.2	00.18
4810	1.0	0.0	00.3	00.22
4820	2.0	0.3	00.5	00.37
4830	4.9	0.6	01.0	00.64
4840	10.6	1.3	02.4	01.7
4850	20.5	4.5	08.0	05.4
4860	31.0	14.5	22.0	16.0
4870	40.0	29.5	38.0	32.0
4880	39.0	40.0	44.0	42.0
4890	27.5	42.5	44.0	46.0
4900	16.0	40.5	40.0	45.0
4910	8.0	30.5	26.0	37.0
4920	3.4	12.0	11.0	20.0
4930	1.6	4.5	03.6	08.0
4940	0.7	1.3	01.0	02.6
4950	0.4	0.3	00.4	00.7

All optical systems blocked to 0.05% transmission or less outside passband. This is an experimentally determined value which takes into account all pinholes present in the filters.

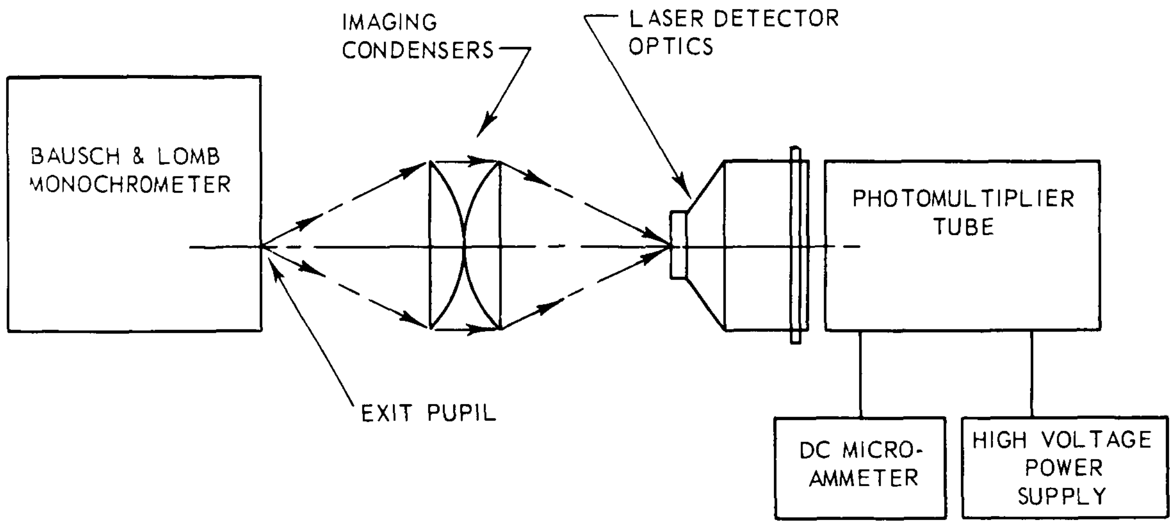

Figure 2.1.1-1. Spectral Transmission Test of Laser Detector Optics

2.1.2 Laser Detector Response Versus Angle of Incidence — The entrance pupil of the detector is 0.60 inches in diameter, and has an area of 0.282 square inches (1.83 square centimeters). As the detector is tilted, so that incident laser radiation is not normal to the entrance pupil (parallel to the optical system axis) the effective area of the system is reduced approximately by the $\cos^4$ law. A test to determine the exact amount of loss of effective area versus incidence angle has been performed and the results are shown in Table 2.1.2 and Figure 2.1.2. This test was performed only on Unit No. 1. Due to the similarity of units this curve should suffice for all of the units.

2.2 Photoelectric Sensor

2.2.1 DC Anode Radiant Sensitivity — The detectors were placed 100 centimeters from spectral irradiance standard No. 1 with a neutral density filter with a transmission of 0.0172 over the entrance pupil. The power incident on the phototube was:

$$P = A T_f \int_0^\infty H_\lambda T_{\Delta\lambda} \, d\lambda$$

where A is the area of the entrance pupil (1.82 cm^2), T_f is the neutral density filter transmission, $T_{d\lambda}$ is the detector spectral filter transmission, H_λ is the

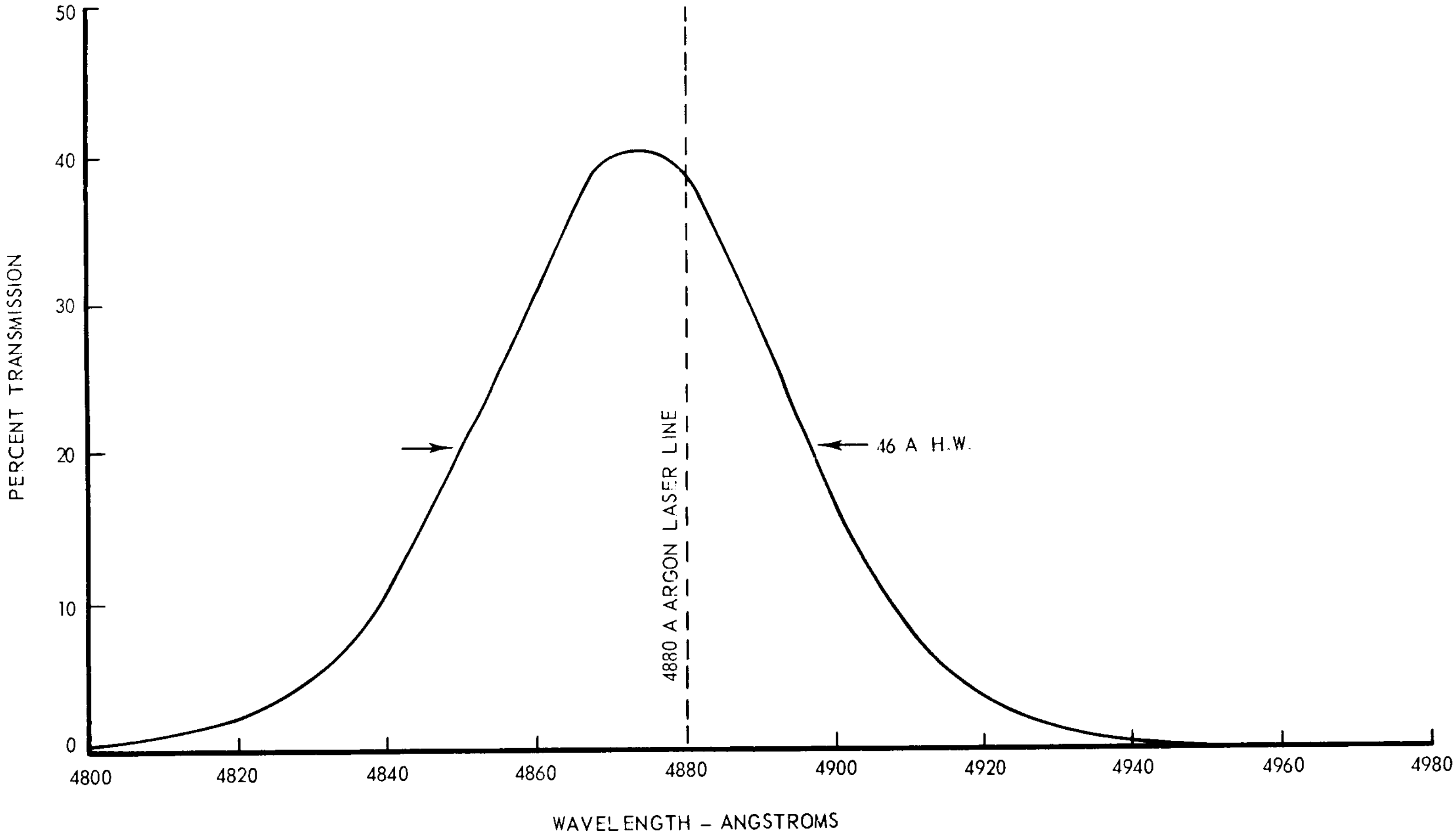

Figure 2.1.1-3. Spectral Transmission of Optical System of Laser Detector — Unit #1

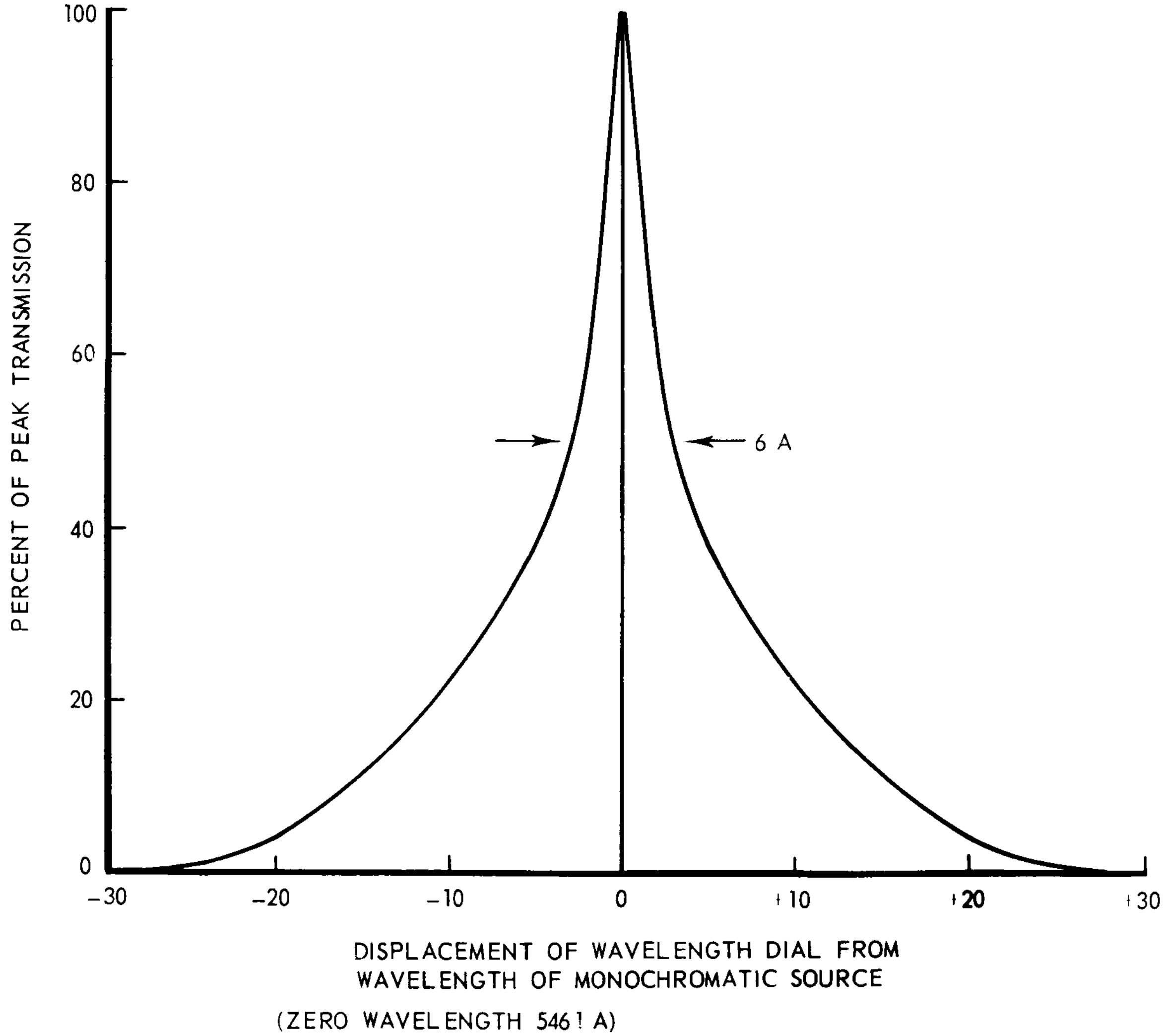

Figure 2.1.1-2. Spectral Resolution of B&L Monochrometer With Slits Set At 0.25 × 10 MM
5/3/67

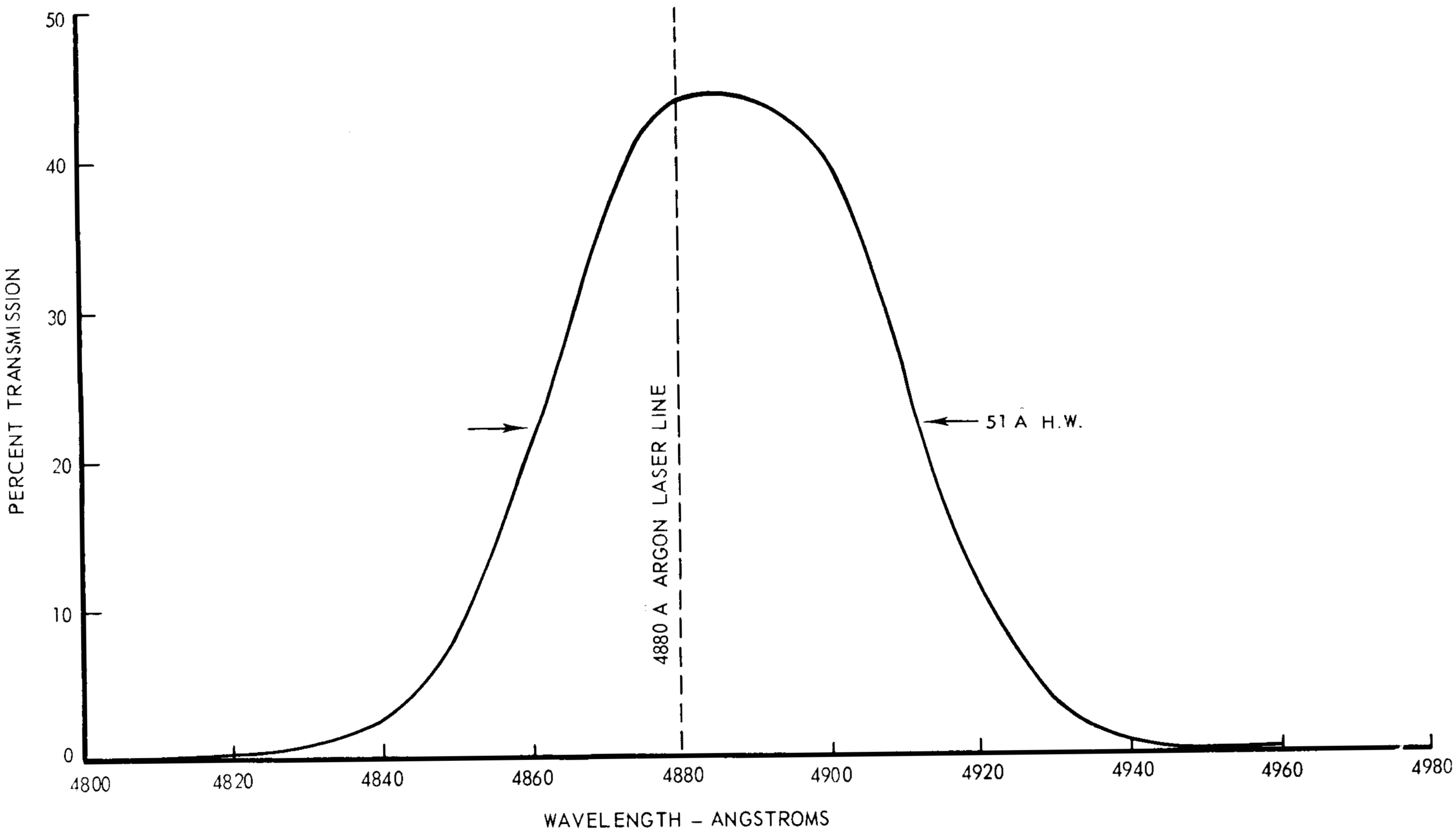

Figure 2.1.1-5. Spectral Transmission of Optical System of Laser Detector — Unit #3

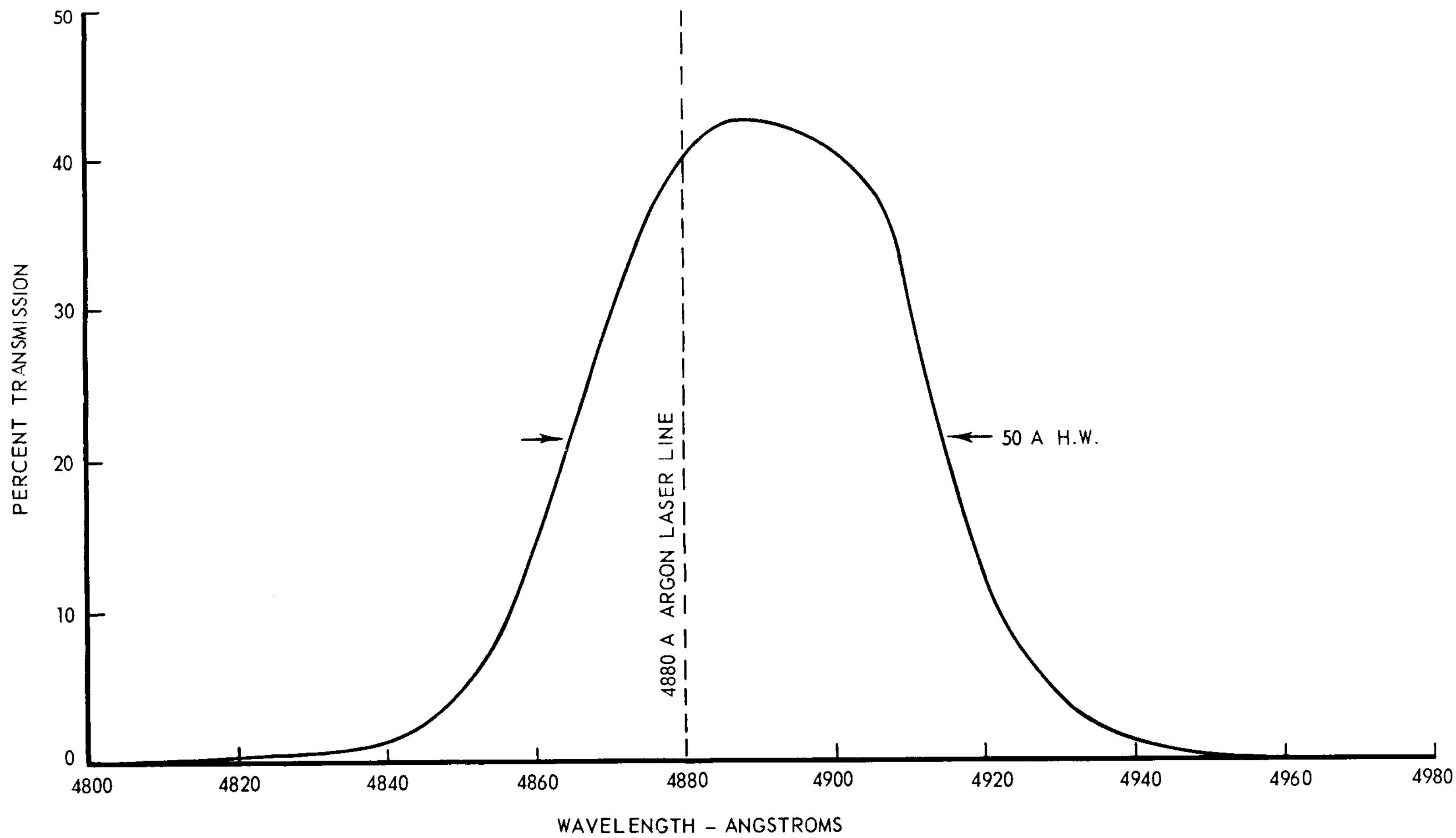

Figure 2.1.1-4. Spectral Transmission of Optical System of Laser Detector — Unit #2

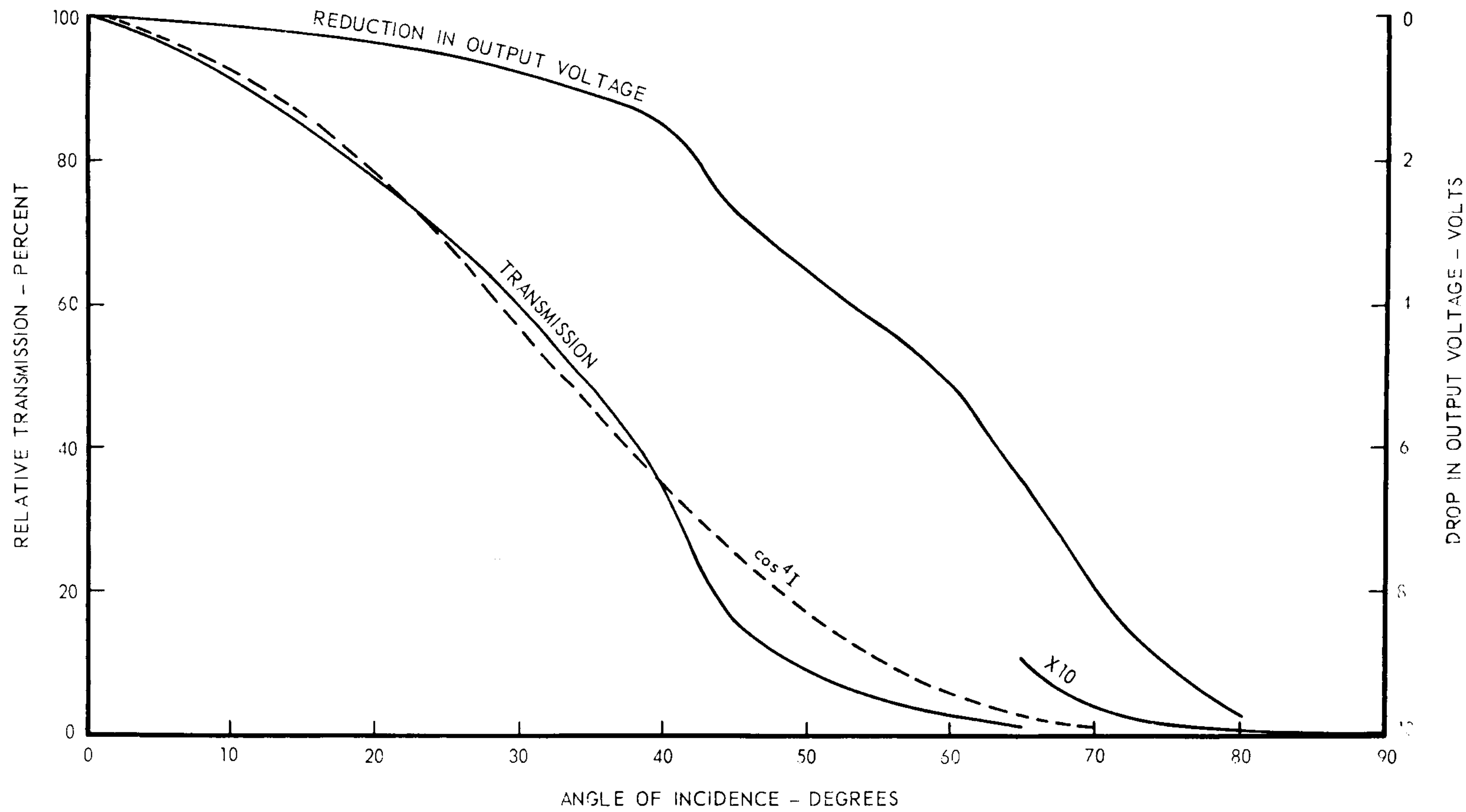

Figure 2.1.2. Laser Detector Response Versus Angle of Incidence — Unit # 1

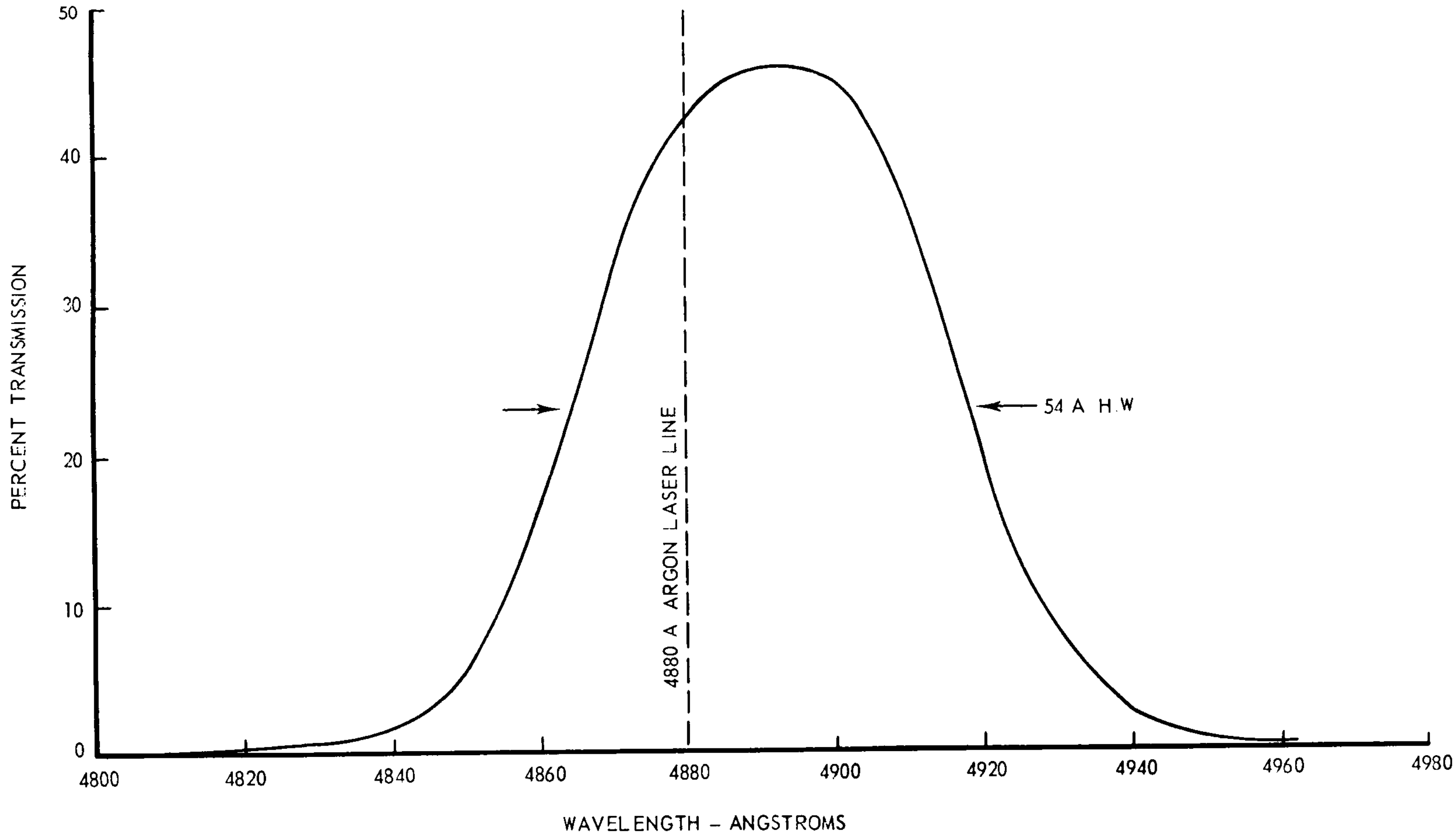

Figure 2.1.1-6. Spectral Transmission of Optical System of Laser Detector — Unit #4

spectral irradiance in watts/cm^{2}Å and λ is the wavelength in Angstroms. A numerical integration of this equation is performed in Tables 2.2.1 - 1, 2.2.1 - 2, 2.2.1 - 3, and 2.2.1 - 4. The resultant output currents and anode radiant sensitivities are shown in Table 2.2.1 - 5. These measurements were made with the trimming resistor circuit open to give infinity resistance. Trimming resistors were added later to adjust the gain of the detector.

Table 2.1.1-6 gives the spectral irradiance of the standard.

Table 2.1.2

Laser Detector Response Versus Angle of Incidence — Unit #1

Angle of Incidence (I) (Degrees)	Output (Volts)	Loss		$\cos^4 I$
		Volts	db	
0	5.00	0	0	1.00
5	4.94	0.06	0.18	
10	4.85	0.15	0.45	0.94
15	4.75	0.25	0.75	
20	4.62	0.38	1.14	0.78
25	4.42	0.58	1.74	
30	4.20	0.80	2.40	0.56
35	3.90	1.10	3.30	
40	3.50	1.50	4.50	0.34
45	2.30	2.70	8.10	
50	1.55	3.45	10.35	0.17
55	0.70	4.30	12.90	
60	-0.15	5.15	15.40	0.06
65	-1.50	6.50	19.50	
70	-3.00	8.00	24.00	0.14
75	-4.00	9.00	27.00	
80	-4.75	9.75	29.20	
85	-5.15	10.15	30.50	
90	-5.20	10.20	30.60	

Table 2.2.1 - 2

DC Anode Radiant Sensitivity Unit #2

λ	H_λ	$T_{D\lambda}$	$d\lambda$	$H_\lambda T_{D\lambda} d\lambda$
4800	3.42×10^{-9}	0.000	±5	0.00×10^{-9}
4810	3.47	0.002	±5	0.07×10^{-9}
4820	3.53	0.003	±5	0.11×10^{-9}
4830	3.58	0.008	±5	0.29×10^{-9}
4840	3.63	0.013	±5	0.47×10^{-9}
4850	3.68	0.028	±5	1.03×10^{-9}
4860	3.73	0.145	±5	5.40×10^{-9}
4870	3.78	0.290	±5	10.95×10^{-9}
4880	3.83	0.400	±5	15.32×10^{-9}
4890	3.88	0.426	±5	16.50×10^{-9}
4900	3.93	0.405	±5	15.90×10^{-9}
4910	3.98	0.310	±5	12.32×10^{-9}
4920	4.03	0.125	±5	5.04×10^{-9}
4930	4.08	0.043	±5	1.75×10^{-9}
4940	4.14	0.012	±5	0.50×10^{-9}
4950	4.19	0.002	±5	0.08×10^{-9}

$$\Sigma H_\lambda T_D \lambda d\lambda = 85.73 \times 10^{-9}$$
$$= 8.57 \times 10^{-8} \text{ watts/cm}^2$$

$$P = A T_F \int_0^\infty H_\lambda T_{\Delta\lambda} d\lambda$$

$$= 1.82 \times 0.0172 \times 8.52 \times 10^{-8} = 0.267 \times 10^{-8} = 2.67 \times 10^{-9} \text{ watts}$$

Table 2.2.1 - 1

DC Anode Radiant Sensitivity Unit #1

λ	H_λ	$T_{D\lambda}$	$d\lambda$	$H_\lambda T_{D\lambda} d\lambda$
4800	3.42×10^{-9}	0.007	±5	0.24×10^{-9}
4810	3.47	0.010	±5	0.35×10^{-9}
4820	3.53	0.020	±5	0.72×10^{-9}
4830	3.58	0.049	±5	1.78×10^{-9}
4840	3.63	0.106	±5	3.90×10^{-9}
4850	3.68	0.205	±5	7.55×10^{-9}
4860	3.73	0.310	±5	11.58×10^{-9}
4870	3.78	0.400	±5	15.10×10^{-9}
4880	3.83	0.390	±5	14.91×10^{-9}
4890	3.88	0.275	±5	10.69×10^{-9}
4900	3.93	0.160	±5	6.29×10^{-9}
4910	3.98	0.080	±5	3.18×10^{-9}
4920	4.03	0.034	±5	1.37×10^{-9}
4930	4.08	0.016	±5	0.65×10^{-9}
4940	4.14	0.007	±5	0.29×10^{-9}
4950	4.19	0.004	±5	0.17×10^{-9}

$$\Sigma H_\lambda T_D \lambda\, d\lambda = 78.77 \times 10^{-9}$$
$$= 7.87 \times 10^{-8} \text{ watts/cm}^2$$

$$P = A\, T_F \int_0^\infty H_\lambda T_{\Delta\lambda}\, d\lambda$$

$$= 1.82 \times 0.0172 \times 7.87 \times 10^{-8} = .246 \times 10^{-8} = 2.46 \times 10^{-9} \text{ watts}$$

Table 2.2.1 - 4

DC Anode Radiant Sensitivity Unit #4

λ	H_λ	$T_{D\lambda}$	$d\lambda$	$H_\lambda T_{D\lambda} d\lambda$
4800	3.42×10^{-9}	.0018	±5	0.06×10^{-9}
4810	3.47	.0022	±5	0.08×10^{-9}
4820	3.53	.0037	±5	0.13×10^{-9}
4830	3.58	.0064	±5	0.23×10^{-9}
4840	3.63	.017	±5	0.62×10^{-9}
4850	3.68	.054	±5	1.99×10^{-9}
4860	3.73	.160	±5	5.96×10^{-9}
4870	3.78	.320	±5	12.49×10^{-9}
4880	3.83	.420	±5	16.10×10^{-9}
4890	3.88	.460	±5	17.85×10^{-9}
4900	3.93	.450	±5	17.70×10^{-9}
4910	3.98	.370	±5	14.71×10^{-9}
4920	4.03	.200	±5	8.08×10^{-9}
4930	4.08	.080	±5	3.26×10^{-9}
4940	4.14	.026	±5	1.08×10^{-9}
4950	4.19	.007	±5	0.11×10^{-9}

$$\Sigma H_\lambda T_D \lambda \, d\lambda = 100.5 \times 10^{-9}$$

$$= 10.1 \times 10^{-8} \text{ watts/cm}^2$$

$$P = A T_F \int_0^\infty H_\lambda T_{\Delta\lambda} d\lambda$$

$$= 1.82 \times 0.0172 \times 10.1 \times 10^{-8} = .326 \times 10^{-8} = .326 \times 10^{-9} \text{ watts}$$

Table 2.2.1 - 3

DC Anode Radiant Sensitivity Unit #3

λ	H_λ	$T_{D\lambda}$	$d\lambda$	$H_\lambda T_{D\lambda} d\lambda$
4800	3.42×10^{-9}	.002	±5	0.07×10^{-9}
4810	3.47	.003	±5	0.10×10^{-9}
4820	3.53	.005	±5	0.18×10^{-9}
4830	3.58	.010	±5	0.36×10^{-9}
4840	3.63	.024	±5	0.87×10^{-9}
4850	3.68	.080	±5	2.95×10^{-9}
4860	3.73	.220	±5	8.20×10^{-9}
4870	3.78	.380	±5	14.38×10^{-9}
4880	3.83	.440	±5	16.85×10^{-9}
4890	3.88	.440	±5	17.08×10^{-9}
4900	3.93	.400	±5	15.71×10^{-9}
4910	3.98	.260	±5	10.38×10^{-9}
4920	4.03	.110	±5	4.44×10^{-9}
4930	4.08	.036	±5	1.47×10^{-9}
4940	4.14	.010	±5	0.41×10^{-9}
4950	4.19	.004	±5	0.17×10^{-9}

$$\Sigma H_\lambda T_D \lambda d\lambda = 93.62 \times 10^{-9}$$
$$= 9.36 \times 10^{-8} \text{ watts/cm}^2$$

$$P = A T_F \int_0^\infty H_\lambda T_{\Delta\lambda} d\lambda$$

$$= 1.82 \times 0.0172 \times 9.36 \times 10^{-8} = 0.293 \times 10^{-8} = 2.93 \times 10^{-9} \text{ watts}$$

Table 2.2.1 - 6

Spectral Irradiance Standard #1

Spectral irradiances in millimicrowatts per square centimeter per Angstrom at a distance of 100 centimeters from the standard. Based on the approximation that:

$$H_\lambda = 5.08 \times 10^{-3} \lambda - 20.96$$

where λ is in Angstroms.

Wavelength (Angstroms)	H_λ (mmw/cm^2 Å)	Wavelength (Angstroms)	H_λ (mmw/cm^2 Å)
4800	3.42	4950	4.19
4810	3.47	4960	4.24
4820	3.53	4970	4.29
4830	3.58	4980	4.34
4840	3.63	4990	4.39
4850	3.68	5000	4.44
4860	3.73		
4870	3.78		
4880	3.83		
4890	3.88		
4900	3.93		
4910	3.98		
4920	4.03		
4930	4.08		
4940	4.14		

Table 2.2.1 - 5

Anode Radiant Sensitivity Test Data Summary Sheet

Test Data	Unit #1	Unit #2	Unit #3	Unit #4
Incident Power (watts)	2.46×10^{-9}	2.67×10^{-9}	2.93×10^{-9}	3.26×10^{-9}
Output Current (Amps)	5.80×10^{-6}	1.90×10^{-6}	0.80×10^{-6}	1.40×10^{-6}
Anode Radiant Sensitivity (Amps/watt)	2.36×10^{3}	7.12×10^{2}	2.72×10^{2}	4.30×10^{2}
Manufacturers Data				
DC Bias (Volts)	1890	1865	1840	1795
Gain	10^5	10^5	10^5	10^5
Anode Radiant Sensitivity (Amps/watt)	1.20×10^{3}	2.20×10^{3}	2.05×10^{3}	1.26×10^{3}

Unit #1 Table 2.3 - 1 Date: 3-17-67

Input/Output for Signal Processing System

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	5.031
						10	3.363
						20	1.696
14.7	25°C	13004	—	72	15.5 min.	30	0.033
						40	-1.634
						50	-3.323
						60	-5.065
						0	5.013
						10	3.333
						20	1.668
13.23	25°C	13001	—	72	15.5 min.	30	-0.003
						40	-1.673
						50	-3.348
						60	-4.987
						0	5.022
						10	3.341
						20	1.675
16.17	25°C	13008	—	73	15.5 min.	30	0.002
						40	-1.669
						50	-3.360
						60	-5.085
						0	5.125
						10	3.387
						20	1.664
14.7	50°C	12996	—	82	14.5 min.	30	-0.063
						40	-1.787
						50	-3.492
						60	-4.954

0 db Input 4.65×10^{-3} volts rms

2.2.2 Solar Radiation Damage to Detector — The laser detector (Unit No. 1) was placed on a lens bench to test its sensitivity. Spectral irradiance standard No. 1 was placed on the bench 100 cm from a 13,000 Hz chopper wheel with 0.0312 inch diameter holes. The detector was placed directly behind the chopper. With the standard operating at 0.50 amps the detector output was +4.2 volts.

The detector was pointed at the sun for 60 seconds with power on. Anode current was 104 microamps.

After exposure to the sun, the sensitivity of the detector was retested on the lens bench and the output was +4.3 volts. The increase in output is believed to be due to increased dark current.

The conclusion reached from this test is that the detector may be directly exposed to the sun for short periods without any appreciable damage.

2.3 Signal Processing System.

The signal processing system is defined as all of the circuitry between the output of the photomultiplier, and the output terminals to the satellite. Since this portion of the laser detector can be tested entirely electrically, detailed tests of the linearity, filter response, and turn off time as a function of temperature and supply voltage were performed. The tests consisted of feeding in a signal from a signal generator and measuring the output. Results are shown in Tables 2.3 - 1 through 2.3 - 4 and are largely self explanatory. Note however, that the term Low refers to the 30 Hz output, and High refers to the 80 Hz output.

Unit #1 Table 2.3 - 1 (Continued) Date: 3-17-67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	5.054
						10	3.353
						20	1.668
16.17	0°C	13004	—	81	6.5 min.	30	-0.023
						40	-1.722
						50	-3.466
						60	-5.310
						0	5.274
						10	3.530
						20	1.805
14.70	-20°C	12995	—	80	6.5 min.	30	0.080
						40	-1.635
						50	-3.336
						60	-5.017
						0	5.274
						10	3.532
						20	1.810
13.23	-20°C	12993	—	80	6.5 min.	30	0.086
						40	-1.630
						50	-3.339
						60	-5.028
						0	5.269
						10	3.528
						20	1.805
16.17	-20°C	12994	—	80	6.5 min.	30	0.080
						40	-1.640
						50	-3.357
						60	-5.085

Unit #1 Table 2.3 - 1 (Continued) Date: 3-17-67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	5.122
						10	3.386
						20	1.663
13.23	50°C	12994	—	82	14.5 min.	30	-0.061
						40	-1.779
						50	-3.462
						60	-4.960
						0	5.112
						10	3.379
						20	1.660
16.17	50°C	12997	—	84	14.5 min.	30	-0.061
						40	-1.781
						50	-3.491
						60	-5.082
						0	5.039
						10	3.335
						20	1.645
14.70	0°C	13000	—	81	6.5 min.	30	-0.050
						40	-1.752
						50	-3.484
						60	-5.310
						0	5.071
						10	3.368
						20	1.680
13.23	0°C	13004	—	81	6.5 min.	30	-0.012
						40	-1.712
						50	-3.438
						60	-5.246

Unit #2 Table 2.3 - 2 (Continued) Date: 6-1-67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+4.950
						10	+3.277
						20	+1.628
13.23 v	+50°C	12987	33	81	15.3 min.	30	-0.014
						40	-1.672
						50	-3.327
						60	-5.018
						0	+4.936
						10	+3.264
						20	+1.615
16.17 v	+50°C	12989	34	80	15.3 min.	30	-0.030
						40	-1.686
						50	-3.340
						60	-5.013
						0	+5.053
						10	+3.337
						20	+1.642
14.7 v	0°C	12986	32	84	16.0 min.	30	-0.047
						40	-1.745
						50	-3.464
						60	-5.382
						0	+5.058
						10	+3.337
						20	+1.641
13.23 v	0°C	12987	31	84	16.0 min.	30	-0.052
						40	-1.755
						50	-3.470
						60	-5.388

Unit #2 Table 2.3 - 2 Date: 6-1-67

Input/Output for Signal Processing System

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.022
						10	+3.336
						20	+1.673
14.7 v	25°C	13000	32	84	15.5 min.	30	+0.008
						40	-1.647
						50	-3.332
						60	-5.023
						0	+5.021
						10	+3.338
						20	+1.678
13.23 v	25°C	12999	32	82	15.5 min.	30	+0.019
						40	-1.639
						50	-3.322
						60	-5.013
						0	+5.001
						10	+3.331
						20	+1.669
16.17 v	25°C	13001	32	82	15.5 min.	30	+0.006
						40	-1.655
						50	-3.339
						60	-5.035
						0	+4.940
						10	+3.268
						20	+1.619
14.7 v	+50°C	12988	33	80	15.3 min.	30	-0.025
						40	-1.680
						50	-3.339
						60	-5.022

Unit #3 | Table 2.3 - 3 | Date: 6/15/67

Input/Output for Signal Processing System

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.033
						10	+3.373
						20	+1.729
14.7 v	25°C	13009	33	81	15.7 min.	30	+0.080
						40	-1.583
						50	-3.270
						60	-5.049
						0	+5.032
						10	+3.375
						20	+1.728
13.23	25°C	13008	32	82	—	30	+0.076
						40	-1.580
						50	-3.273
						60	-5.046
						0	+5.040
						10	+3.382
						20	+1.733
16.17	25°C	13010	33	83	—	30	+0.083
						40	-1.572
						50	-3.275
						60	-5.035
						0	+5.162
						10	+3.456
						20	+1.758
14.7	0°C	12998	33	84	16.3 min.	30	+0.061
						40	-1.639
						50	-3.358
						60	-5.158

P.M. #3 P.S. #5

0 db level .0095 volts rms to pins #7 & #12

Unit #2 Table 2.3 - 2 (Continued) Date: 6-1-67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.047
						10	+3.327
						20	+1.630
16.17 v	0°C	12986	32	85	16.0 min.	30	-0.061
						40	-1.760
						50	-3.473
						60	-5.389
						0	+5.067
						10	+3.389
						20	+1.736
14.7 v	-20°C	12968	31	79	17.2 min.	30	+0.092
						40	-1.549
						50	-3.194
						60	-5.102
						0	+5.086
						10	+3.399
						20	+1.742
13.23 v	-20°C	12969	30	80	17.2 min.	30	+0.094
						40	-1.547
						50	-3.193
						60	-5.063
						0	+5.048
						10	+3.371
						20	+1.724
16.17 v	-20°C	12970	30	81	17.2 min.	30	+0.085
						40	-1.552
						50	-3.178
						60	-5.045

Unit #3 Table 2.3 - 3 (Continued) Date: 6/15/67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.185
						10	+3.487
						20	+1.802
16.17	-20°C	12984	31	80	—	30	+0.116
						40	-1.563
						50	-3.247
						60	-5.046
						0	+4.966
						10	+3.333
						20	+1.715
14.7	+50°C	12995	32	82	14.5 min.	30	+0.094
						40	-1.538
						50	-3.213
						60	-4.905
						0	+4.957
						10	+3.324
						20	+1.703
13.23	+50°C	12997	32	82	—	30	+0.079
						40	-1.552
						50	-3.232
						60	-4.908
						0	+4.982
						10	+3.347
						20	+1.729
16.17	+50°C	12996	31	82	—	30	+0.103
						40	-1.530
						50	-3.214
						60	-4.912

Unit #3 Table 2.3 - 3 (Continued) Date: 6/15/67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.156
						10	+3.452
						20	+1.757
13.23	0°C	12998	33	84	—	30	+0.063
						40	-1.633
						50	-3.350
						60	-5.152
						0	+5.150
						10	+3.446
						20	+1.751
16.17	0°C	12998	33	84	—	30	+0.055
						40	-1.637
						50	-3.354
						60	-5.163
						0	+5.208
						10	+3.501
						20	+1.806
14.7	-20°C	12985	32	81	17.5 min.	30	+0.113
						40	-1.576
						50	-3.265
						60	-5.055
						0	+5.196
						10	+3.498
						20	+1.812
13.23	-20°C	12984	31	80	—	30	+0.126
						40	-1.548
						50	-3.227
						60	-5.036

Unit #4 Table 2.3 - 4 (Continued) Date: 6/20/67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.073
						10	+3.335
						20	+1.610
13.23 v	0°C	13006	31	81	—	30	-0.098
						40	-1.774
						50	-3.434
						60	-5.051
						0	+5.070
						10	+3.334
						20	+1.612
16.17 v	0°C	13006	31	82	—	30	-0.087
						40	-1.776
						50	-3.422
						60	-5.038
						0	+5.044
						10	+3.341
						20	+1.664
14.7 v	-20°C	12988	32	80	16.5 min.	30	+0.002
						40	-1.652
						50	-3.265
						60	-4.963
						0	+5.048
						10	+3.351
						20	+1.675
13.23 v	-20°C	12987	33	80	—	30	+0.011
						40	-1.623
						50	-3.229
						60	-4.941

Unit #4 | Table 2.3 - 4 | Date: 6/20/67

Input/Output for Signal Processing System

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.001
						10	+3.256
						20	+1.542
14.7 v	+25°C	13006	30	80	14.7 min.	30	+0.158
						40	-1.840
						50	-3.465
						60	-5.010
						0	+4.997
						10	+3.260
						20	+1.548
13.23 v	+25°C	13006	31	81	—	30	-0.151
						40	-1.828
						50	-3.462
						60	-4.997
						0	+5.016
						10	+3.275
						20	+1.561
16.17 v	+25°C	13006	30	80	—	30	-0.142
						40	-1.820
						50	-3.460
						60	-4.978
						0	+5.082
						10	+3.333
						20	+1.612
14.7 v	0°C	13005	31	82	15.5 min.	30	-0.090
						40	-1.780
						50	-3.448
						60	-5.064

PM #2

0 db level .0061 volts rms to pins #7 & #12

2.4.1 Overall Optical/Electrical Calibration — The detector was placed on a Gaertner bench 100 cm from Secondary Standard of Spectral Radiance No. 1. A chopper wheel with 0.0312 inch holes (4.95×10^{-3} cm^2 area) was placed directly in front of the detector running at a speed of 13020 Hz. Between the detector, and chopper, a 0.0172 transmission neutral density filter was placed to reduce intensity. The energy reaching the detector at the peak of the chopper cycle is therefore:

$$P = AT_f \int_0^{\infty} H_\lambda \, T_{d\lambda} \, d\lambda$$

where A is the area of the chopper hole, T_f is the transmission of the neutral density filter, H_λ is the spectral irradiance in watts/cm^2 Å and λ is the wavelength in Angstroms. Using the values for the integral evaluated in the DC anode radiant sensitivity tests we get

$$P_1^* = 4.95 \times 10^{-3} \times 1.72 \times 10^{-2} \times 7.87 \times 10^{-8} = 6.70 \times 10^{-12} \text{ watts}$$

$$P_2 = 4.95 \times 10^{-3} \times 1.72 \times 10^{-2} \times 8.57 \times 10^{-8} = 7.32 \times 10^{-12} \text{ watts}$$

$$P_3 = 4.95 \times 10^{-3} \times 1.72 \times 10^{-2} \times 9.36 \times 10^{-8} = 7.99 \times 10^{-12} \text{ watts}$$

$$P_4 = 4.95 \times 10^{-3} \times 1.72 \times 10^{-2} \times 10.1 \times 10^{-8} = 8.58 \times 10^{-12} \text{ watts}$$

The voltages corresponding to these powers should be

$$V_1 = 3.33 \log \frac{6.70 \times 10^{-12}}{10^{-13}} - 5 = +1.09 \text{ volts}$$

$$V_2 = 3.33 \log \frac{7.32 \times 10^{-12}}{10^{-13}} - 5 = +1.24 \text{ volts}$$

$$V_3 = 3.33 \log \frac{7.99 \times 10^{-12}}{10^{-13}} - 5 = +1.34 \text{ volts}$$

$$V_4 = 3.33 \log \frac{8.58 \times 10^{-12}}{10^{-13}} - 5 = +1.42 \text{ volts}$$

*Subscripts refer to detector number

Unit #4 | Table 2.3 - 4 (Continued) | Date: 6/20/67

Input Voltage	Temp °C	Peak Freq. (Hertz)	3db Freq.(Low) (Hertz)	3db Freq.(High) (Hertz)	Turn Off Time	Input Attenuation (db)	Output (volts)
						0	+5.034
						10	+3.337
						20	+1.663
16.17 v	-20°C	12987	32	82	—	30	+0.003
						40	-1.635
						50	-3.236
						60	-4.940
						0	+4.925
						10	+3.163
						20	+1.436
14.7 v	+50°C	13014	31	83	14.2 min.	30	-0.262
						40	-1.937
						50	-3.551
						60	-5.027
						0	+4.923
						10	+3.172
						20	+1.440
13.23v	+50°C	13013	31	82		30	-0.260
						40	-1.932
						50	-3.554
						60	-5.032
						0	+4.912
						10	+3.151
						20	+1.420
16.17 v	+50°C	13013	31	82		30	-0.286
						40	-1.962
						50	-3.581
						60	-5.069

UNIT NO. 3 UNIT NO. 4

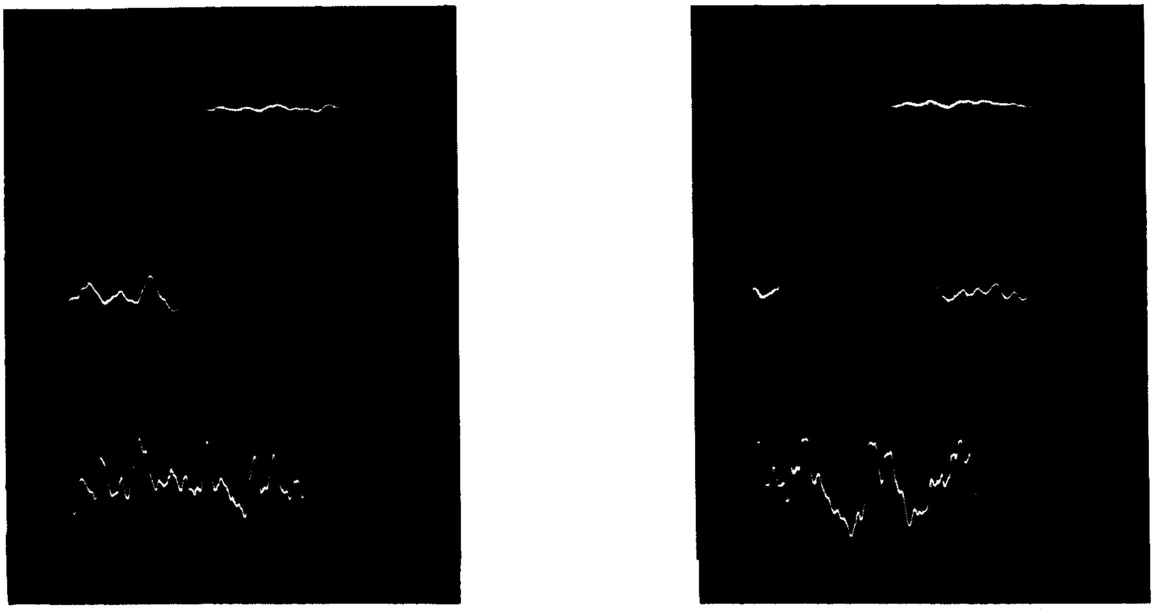

Figure 2.4.2 – 1.

Results are in peak to peak volts output with the carrier set to give an output of +3 volts. The power ratio can be defined in terms of the percent modulation as follows:

$$\text{Power Ratio} = \frac{E_c + E_m}{E_c - E_m} = \frac{E_c\left[1 + m\right]}{E_c\left[1 - m\right]} = \frac{1 + m}{1 - m}$$

Since 1 db = 0.33 volts on the detector, the following conversion between percent modulation and expected voltage swing can be made:

Percent Modulation		Power Ratio		Voltage Swing
80% = 1.8/0.2	=	9 = 9.55 db	=	3.18 volts
60% = 1.6/0.4	=	4 = 6.0 db	=	2.0 volts
40% = 1.4/0.6	=	2.34 = 3.7 db	=	1.23 volts
20% = 1.2/0.8	=	1.50 = 1.75 db	=	0.53 volts
10% = 1.1/0.9	=	1.22 = 0.86 db	=	0.26 volts

Results are shown graphically in Figure 2.4.4 - 1.

Voltages were set to the following values:

	Trim Resistor (ohms)
$V_1 = 1.09$	Unknown
$V_2 = 1.24$	22K
$V_3 = 1.50$	20K
$V_4 = 1.38$	68K

2.4.2 Output Noise — The noise in the 80 Hz output of detectors No. 3 and No. 4 has been recorded by feeding in an optical signal chopped at 13020 Hz corresponding to an output voltage of +5, 0, and -5 volts. The 13020 Hz carrier was unmodulated. Output was photographed on an oscilloscope. Sweep speed was 10 milliseconds per centimeter, and vertical sensitivity 1 volt per centimeter. Results are as follows:

Detector Number	Average Output Level (Volts)	Peak to Peak Noise (Volts)
3	+5	0.3
3	0	1.2
3	-5	2.6
4	+5	0.3
4	0	0.8
4	-5	3.0

Photographs of the scope traces are shown in the photographs of Figure 2.4.2 - 1.

2.4.3 Modulation Response — A 13000 Hz signal was fed into the detector on pins 7 and 12 and set to give an output of +3 volts. Amplitude modulations of the carrier from 20 through 640 Hz were applied with percent modulation varying from 10% to 80%. Output voltage swing of the detector was measured, and its peak to peak value recorded for each percent modulation and frequency. Percent modulation was defined by Em the peak to trough height of the modulation divided by Ec the peak to peak carrier height. The following results were obtained:

	Modulation Frequency					
Percent Modulation	20	40	80	160	320	640
80%	3.1	2.7	1.70	0.80	0.25	0.05
60%	2.0	1.75	1.20	0.60	0.20	0.05
40%	1.30	1.20	0.80	0.40	0.15	0.03
20%	0.70	0.65	0.45	0.20	0.10	0
10%	0.40	0.40	0.25	0.13	0.07	0

2.4.4 Telemetry System Interface — A test was performed on the GEOS-B satellite during lids off testing to see if the output of the laser detector was correctly coupled to the telemetry system. A signal generator was used to feed in a 13000 Hz signal between pins 7 and 12. A jumper cable allowed the output of the detector to be measured for both the 30 and 80 Hz channels. The 30 and 80 Hz channels were then connected to the satellite and the output of the laser detector was compared to the output of the telemetry system. A digital voltmeter maintained the laser detector output terminals while they were converted to the satellite.

Output Voltage of Laser Detector During Telemetry Interface Testing

Dot Connected to Satellite	Connected to Satellite		Telemetry Output	
	30 Hz	80 Hz	30 Hz	80 Hz
5.00	4.77	3.77	5.00	4.99
4.00	3.81	3.81	4.01	4.01
3.00	2.86	2.86	3.02	3.02
2.00	1.91	1.91	2.03	2.04
1.00	0.96	0.96	1.04	1.04
0.00	0.00	0.00	0.03	0.05
-1.00	-0.94	-0.94	-0.95	-0.95
-2.01	-1.90	-1.90	-1.95	-1.95
-3.00	-2.85	-2.85	-2.94	-2.94
-4.00	-3.90	-3.30	-4.01	-4.01
-5.00	-4.80	-4.80	-5.07	-5.06
-5.75	-5.70	-5.70	-5.98	-5.98

Test Data taken 8-24-67

Operating Voltage +15.1 volts.

2.4.5 Regulation with Respect to Supply Voltage — The laser detector (Unit No. 1) was set up with a chopped light source impinging on the entrance pupil. Energy was adjusted to give readings of -5.0, 0.0, and +5.0 by varying bulb brightness. Initial settings were made at +15.0 volts supply voltage. At each of the output voltages, supply voltage was varied, and output voltage recorded for each supply voltage.

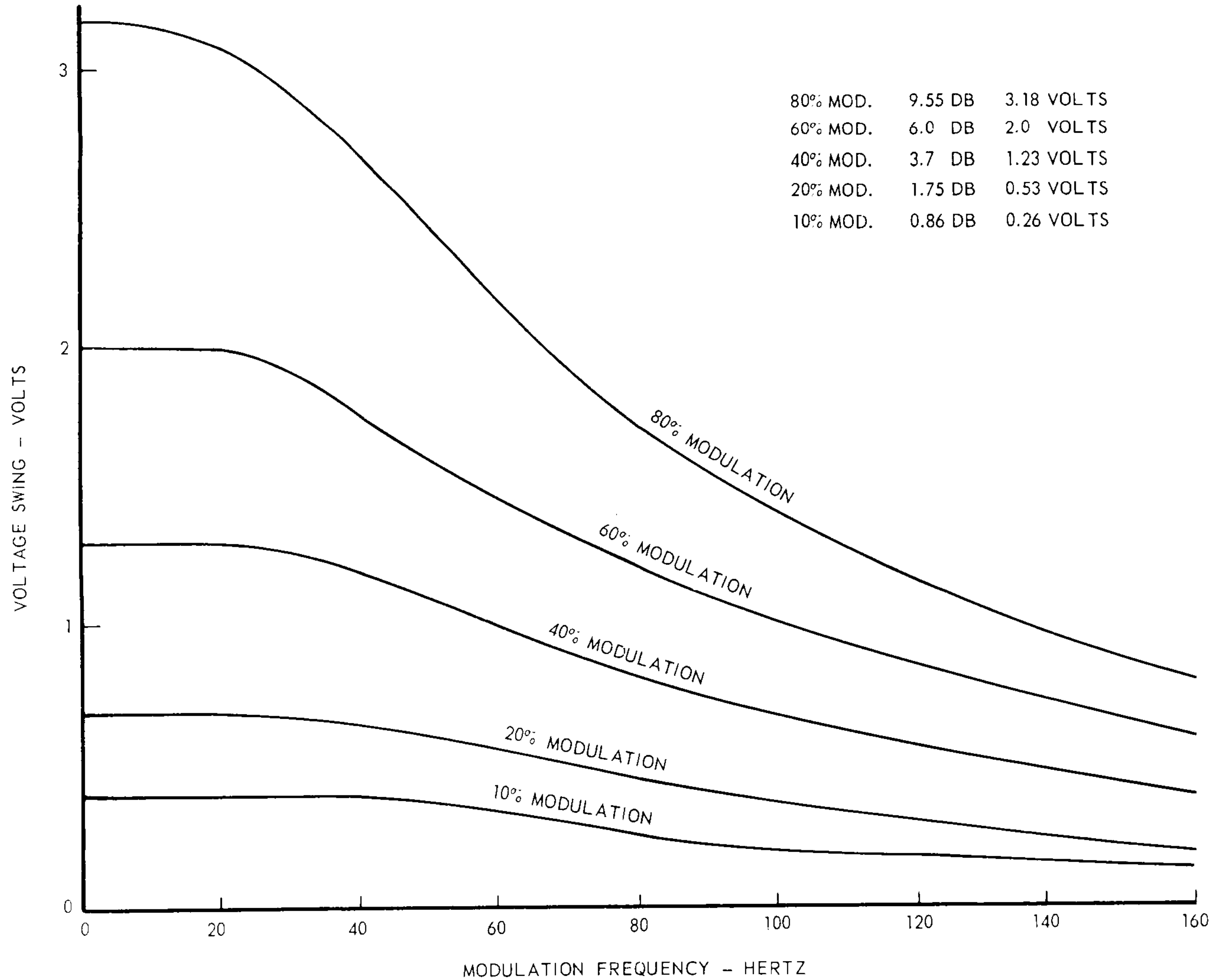

Figure 2.4.4 – 1. Modulation Response – 80 Hz Output

Supply Voltage	Output -5.0	Output 0.0	Output +5.0
5	-1.6	-0.60	+2.0
6	-2.8	+0.20	+2.6
7	-3.4	+0.60	+3.0
8	-3.8	+0.45	+3.6
9	-4.8	+0.30	+4.2
10	-5.0	+0.07	+4.7
11	-5.0	+0.0	+5.0
12	-5.0	+0.0	+5.0
13	-5.0	+0.0	+5.0
14	-5.0	+0.0	+5.0
15	-5.0	+0.0	+5.0
16	-5.0	+0.0	+5.0
17	-5.0	+0.0	+5.0
18	-5.0	+0.0	+5.0
19	-5.0	+0.0	+5.0
20	-5.0	+0.0	+5.0